TECHNICAL REPORT

FD-20

# DEVELOPMENT OF FOOD BARS EMPLOYING EDIBLE STRUCTURAL AGENTS

by

H. E. Newlin

E. R. Morris

**MIDWEST RESEARCH INSTITUTE**
**Kansas City 10, Missouri**

**Contract No. DA 19-129-QM-1984 (OI 6071)**

August 1965

**U. S. Army Materiel Command**

U. S. ARMY NATICK LABORATORIES

**Natick, Massachusetts**

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official indorsement or approval of the use of such items.

## DDC AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report from Commanding Officer, Defense Documentation Center (DDC) (formerly ASTIA), Cameron Station, Alexandria, Virginia 22314.

Released to the Clearing House for Federal Scientific and Technical Information, Springfield, Virginia 22151, for sale to the public.

## DISPOSITION INSTRUCTIONS

Destroy; do not return.

AD

# TECHNICAL REPORT
# FD-20

# DEVELOPMENT OF FOOD BARS EMPLOYING EDIBLE STRUCTURAL AGENTS

by

H. E. Newlin E. R. Morris

MIDWEST RESEARCH INSTITUTE
425 Volker Boulevard
Kansas City 10, Missouri

Contract No. DA19-129-QM-1984 (OI 6071)

Project Reference:
7X84-06-031

August 1965

U. S. Army Materiel Command

U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

# FOREWORD

This investigation represents one of a series of projects which was undertaken in response to a requirement for the development of lightweight, individual combat food packets to be carried on the person. According to Army Regulations 30-40: "Food packets consist of precooked foods which may be eaten hot or cold........ The primary factors considered in their design are maintaining minimum weight and cubage while attaining the maximum in nutrition, palatability, and utility.......". For the food packets under development, collateral requirements relating to over-all weight and caloric content virtually limited consideration to bars from compacted dehydrated foods.

Analysis of deficiencies of food bars currently used in operational rations and of experimental bars formed by compression of various dry foods revealed the need for a generally applicable method for controlling bar cohesion in order to avoid crumbling and breakage and to permit an improved ratio between bar substance and inedible packaging materials. This investigation is directed to the development and demonstration of generally applicable methods for improving the internal cohesion of compressed food bars representing a variety of dehydrated foods of different chemical compositions.

The investigation covered by this report was performed in the Chemical Division of the Midwest Research Institute, 425 Volker Boulevard, Kansas City 10, Missouri. Dr. Harry E. Newlin served as Official Investigator with Dr. E. R. Morris as a collaborator.

Project Officer for the U. S. Army Natick Laboratories was Dr. Maxwell C. Brockmann of the Animal Products Branch, Food Division. Alternate Project Officer was Mr. Albert S. Henick, Food Chemistry Branch, Food Division.

FERDINAND P. MEHRLICH, Ph.D.
Director
Food Division

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

W. W. VAUGHAN
Brigadier General, USA
Commanding

Unclassified
Security Classification

# DOCUMENT CONTROL DATA - R&D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

1. ORIGINATING ACTIVITY (Corporate author)
Midwest Research Institute, Kansas City, Missouri

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
DEVELOPMENT OF FOOD BARS EMPLOYING EDIBLE STRUCTURAL AGENTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final: 10 April 1962 - 10 April

5. AUTHOR(S) (Last name, first name, initial)
NEWLIN, H. E.
MORRIS, E. R.

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| August 1965 | 82 | 0 |

8a. CONTRACT OR GRANT NO.
DA 19-129-QM-1984 (OI 6071)

b. PROJECT NO.
7X84-06-031

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
2591-C

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
FD-20

10. AVAILABILITY/LIMITATION NOTICES
Available at DDC and CFSTI

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Animal Products Branch, Food Division,
U. S. Army Natick Laboratories,
Natick, Mass. 01762

13. ABSTRACT

Several pastes and a hot melt prepared from edible components were found effective binders for preparation of bars from any combination of dry foods. Effectiveness of these edible binders was demonstrated on bars prepared from different types and compositions of foods. Bars remained acceptable after storage for three months at 100°F. and retained adequate resistance to impact and shear.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Development | 8 | | | | | |
| Cohesion | 8 | | | | | |
| Food bars | 2 | | 4 | | 9 | |
| Military rations | 4 | | | | 4 | |
| Preparation (Formulation) | | | 8 | | | |
| Adhesives | | | 9 | | | |
| Food binders | 1 | | 9 | | | |
| Foods (Combination) | 1 | | | | | |
| Dehydrated foods | 1 | | | | | |
| Wet | | | 0 | | | |
| Hot melt | | | 0 | | | |
| Edible | | | 0 | | | |
| Storage stability | | | | | 8 | |
| Impact strength | | | | | 8 | |

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Idenfiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

# TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

## LIST OF TABLES

## LIST OF TABLES (Cont'd)

## ABSTRACT

Several pastes and a hot melt prepared from edible components were found effective binders for preparation of bars from any combination of dry foods. Effectiveness of these edible binders was demonstrated on bars prepared from different types and compositions of food. Bars remained acceptable after storage for three months at 100°F. and retained adequate resistance to impact and shear.

## SUMMARY

We developed edible wet adhesives and an edible hot melt adhesive during the program. These adhesives were capable of binding any combination of solid food components into blocks. The characteristics of food blocks produced with the edible binders were demonstrated both on test blocks and on prototype food blocks. In addition, six different types of food blocks, most of which met the requirements of the contract, were fabricated with the edible binders and shipped to the sponsor for evaluation.

Representative formulas of the edible binders are presented in the following table.

### COMPOSITION OF EDIBLE BINDERS

| Ingredient | Wet Adhesive (%) 1 | 2 | 3 | 4 | Hot Melt Adhesive (%) |
|---|---|---|---|---|---|
| Dry egg albumen | 50 | | | | |
| Dry nonfat milk solids | | | 36 | 50 | |
| Sodium caseinate | | 40 | | | |
| Lactose | | 10 | | | |
| Pregelatinized cornstarch | | | 4 | | |
| Swift Centura gelatin | | | | | 31 |
| Soluble carbohydrate (cerelose) | | | | | 31 |
| Water | 50 | 50 | 60 | 50 | 38 |

The basic test formula used for evaluation of the edible binders consisted of 50 per-cent prefried bacon, 30 per-cent precooked rice, and 20 per-cent dry nonfat milk solids. These ingredients were formed into large (3 x 1-1/2 x 1/2 in.) or small (1-1/4 x 1-1/4 x 1/2 in.) test blocks for binder evaluation.

A thick paste consisting of one part dry nonfat milk solids and one part water adhered firmly to both the bacon and the rice. The use of this adhesive became the basis for the wet binder method. A large number of formulations and processing techniques were investigated in an attempt to improve the adhesive characteristics of the wet binder.

Pretreatment of the ground rice by steeping with bacon or by sizing with adhesive slightly increased the strength of the test blocks. Test blocks were also improved by forming blocks immediately after adding the binder to the bacon and rice. A distinct improvement in the resistance of high moisture blocks made with milk binder was produced by aging for 10 days at room temperature.

A mixture of sodium caseinate (40 per-cent), lactose (10 per-cent), and water (50 per-cent) also showed promise as a binder. Its use was discontinued because it required excessive drying time. A mixture of dry nonfat milk solids (36 per-cent), pregelatinized cornstarch (4 per-cent), and water (60 per-cent) increased the strength of test blocks at high moisture levels. However, this latter composition requires an additional 10 per-cent water in the binder formulation.

A mixture of 50 per-cent dry egg albumen and 50 per-cent water was selected for production of prototype blocks shipped to the sponsor. The selection of egg albumen for the wet binder was based on its availability, ease of preparation, binding characteristics, nutritional adequacy, stability, and favorable physical and organoleptic characteristics it imparted to the food blocks.

Pretreatment of the bacon by dusting or coating with sorbitol, ground rice, wheat gluten, wheat flour or Frodex, followed by conventional tableting methods, permitted increased tableting pressures but failed to yield acceptable blocks.

Edible hot melt binders with very high adhesive strength and containing as little as 33 per-cent moisture were prepared by mixing 31 per-cent Swift Centura gelatin with 31 per-cent soluble carbohydrate such as cerelose, Frodex or sorbitol, and 38 per-cent water. Since the drying process could be shortened and blocks could be made more economically, the application of hot melted adhesives was investigated as a promising alternate to the use of wet adhesives. The melts were applied at temperatures around 120°F, and very strong, although slightly elastic, blocks were obtained after they cooled to room temperature. The two best methods of applying the melts to the experimental test block formula were either to mix them with the bacon and rice, and then form blocks within a few seconds before the melts cooled, or to pour the melts over preformed blocks of the bacon and rice in such a way that the hollow spaces were filled.

Both of the above procedures with hot melts will probably lend themselves well to rapid continuous block formation. Pouring usually required more adhesives than hot mixing. The amount of adhesive was dependent on the percentage of voids in the blocks, and the maximum viscosity which could be used depended on the fineness of the pore structure.

Using the wet binder method with egg albumen as an adhesive, six ration formulas were developed which, in the form of prototype blocks, met the analytical requirements, had good palatability, could be bitten off and chewed, and either met all of the requirements for strength, or appeared capable of meeting these requirements, as needed, by slight adjustment of the formula. These included three meat rations, one each made with bacon, chicken or beef; a cereal formula containing soybean meal and a wheat cracker; as well as a peanut and a coconut dessert ration.

The prototype blocks were stored for 3 months in sealed containers under nitrogen at 100°F. With the exception of a slight hardening in the coconut formula and a slight increase in fragility in the chicken, changes resulting in the measured physical properties were negligible. The acceptability of all rations remained satisfactory. Moderate yellowing and the slight development of a toasted flavor were general. Fresh samples of the six prototype blocks were made and shipped to the sponsor for evaluation.

# I. INTRODUCTION

This is the Final Report covering "Development of Food Bars Employing Edible Structural Agents," authorized by Contract No. DA 19-129-QM-1984 (OI 6071) for the Quartermaster Food and Container Institute for the Armed Forces.

The objective of the program was to develop edible agents for binding any combination of food components into acceptable blocks.

Compressed food bars are often logistically advantageous items for military feeding. Many food components acceptable to the Armed Forces are currently available. However, binding certain of the individual items, as well as combinations of different items, into acceptable blocks still presents unsolved problems. These problems are complicated by many factors. These interrelated factors include widely divergent physical and chemical characteristics of the components. For example, food items differ in particle size, surface characteristics, fragility, moisture content, and stability, as well as in the percentage and distribution of nutritive substances. Therefore, an edible binder possessing the necessary characteristics required to bind any combination of edible food substances into acceptable blocks is needed.

The over-all scope of the program included not only development of the edible binders, but also demonstration of their effectiveness when challenged by:

1. Moisture contents within the range of 1 - 25 per-cent.

2. A maximum concentration of 1.5 per-cent of soluble substances.

3. A temperature range of -65°F to 100°F.

4. A constant temperature of 125°F for 2 hrs.

5. By exposure to three freeze-thaw cycles.

The structural characteristics of food blocks produced with the edible binders were demonstrated with a test block consisting of 50 per-cent prefried bacon, 30 per-cent precooked rice, and 20 per-cent dry non-fat milk solids. Representative physical data on the test block included

shear strength, impact resistance, breaking strength and dimensional stability.

Equilibrium relative humidity curves were determined on the binders used to fabricate the bars submitted to the sponsor.

Application of the edible dried egg albumen binding agent was demonstrated by fabrication and delivery to the sponsor of six different types of food blocks, most of which met the requirements of the contract.

The program demonstrated the feasibility of both a wet and a hot melt adhesive to fabricate food blocks. However, subsequent work will be required before the technology for the use of these materials is fully developed.

The following report describes the development of the wet binder and the hot melt adhesive. Formulation, laboratory procedures, and development of prototype bars are described in the body of the report. Tables and figures showing test results are in the Appendix.

## II. EXPERIMENTAL

### A. Development of a Wet Binder Process for Forming Test Blocks of Prefried Bacon, Precooked Rice and Nonfat Dry Milk

Experimental test blocks consisted of prefried bacon, precooked rice, and nonfat dry milk solids. Each material represented, from a physical standpoint, a group of typical foods which would later be used in preparing prototype blocks.

Prefried bacon was purchased from Oscar-Mayer Company. Precooked rice and nonfat dry milk solids were procured locally. Names and sources of all food materials used in the project are listed in the Appendix.

The bacon, rice and dry milk were combined in a basic test block formula which met the following specifications: Sodium chloride - at least 1.5 per-cent, 20 - 30 per-cent fat, and a minimum of 125 kg cal/oz. The test block formula consisted of 50 per-cent fried bacon,

30 per-cent precooked rice, and 20 per-cent nonfat dry milk solids. The calculated analysis was 9.5 per-cent moisture, 22.3 per-cent protein, 27.8 per-cent fat, 4.6 per-cent ash, and 0.1 per-cent fiber. For preparing test and prototype blocks, the bacon was either ground in a meat grinder with 1/4 x 7/16 in. face plate holes, or cut into small rectangular pieces with scissors. Grinding produced irregular particles with a maximum diameter of from 1/8 to 1/4 in., plus a mixture of finer particles. The rectangular particles cut with scissors were held as close to a 3/8 x 3/8 in. size as practicable. The precooked rice was either used unground, or was ground to desired particle sizes in a Labconco laboratory mill.

1. Basic Test Formula Without Binder

This experiment was conducted to obtain data on the adhesiveness of the test materials. Ground bacon, coarsely ground rice, and powdered milk were mixed in the basic test formula proportions and tableted in a steel die measuring 1-1/4 x 1-1/4 in. A description of this die, subsequently referred to as the small die, appears in the Appendix under the section devoted to equipment. A 10 g. charge of the formula was used for each block, with the result that the average thickness of the blocks was 1/2 in. The ingredient mixture was held for 1 hr., and the blocks were then compressed by means of a Carver laboratory press. Dwell times of 1 - 3 and 15 sec., and total jack pressures of from 500 to 4,000 lb. were used.

To obtain a numerical reference indicating the strength of each block prepared, a breaking test was performed with a modified Warner-Bratzler meat tenderness tester. The results were recorded as breaking strength, in terms of the maximum pressure required to break the blocks. A description of the breaking test equipment and the method used is given in the Appendix.

Table I summarizes the relationship between applied pressure, breaking strength, and fat loss of the small basic test formula blocks compressed without binder. The formula did not withstand more than 2,000 lb. total jack pressure without excessive extrusion of the bacon fat. Breaking strength figures ranging from approximately 1 - 2 lb. corresponded to very soft blocks, which could be easily crushed in the fingers.

2. Wet Adhesive, Milk and Water

Exploratory tests indicated that moistened powdered milk would adhere to the bacon and suggested the use of milk and water as a binding material.

The moisture level of the dry milk was raised in increments from 3.5 to 10.0 per-cent moisture. The moistened milk was mixed with the bacon and rice according to the test block formula, and after holding for about 1 hr., portions representing 10 g. of the original material (not including added water) were weighed out. These were compressed in the small die at pressures varying from 500 - 2,000 lb. with a 3-sec. dwell time. Breaking strengths were immediately determined. All blocks showed breaking strengths under 2 lb. No benefit was obtained from added water.

The above procedure was then modified by increasing the moisture level of the milk in increments ranging from 6.5 - 50 per-cent. Carver press pressures ranging from 500 - 2,000 lb. were applied. Dwell time was approximately 3 sec. Whereas the previous blocks had been tested for breaking strength without drying, those in this experiment were dried to approximately the original weight before determining breaking strength. Drying was carried out in a Despatch circulating hot air oven at a temperature of 100°F. Breaking strengths of about 2 lb. were obtained with moisture levels of 20 per-cent and lower in the milk binder. When adjusted to 30 and 40 per-cent moisture, the milk binder became granular. The resultant blocks had lower breaking strengths than blocks fabricated with less water in the binder. However, when the milk was adjusted to 50 per-cent moisture, a paste-type binder composition was obtained which improved the breaking strength of the finished blocks. Breaking strengths of from 4 - 10 lb. were obtained on the latter blocks. In further experiments rice and bacon were bound separately with a binder consisting of equal parts of nonfat dry milk and water. In the first of these, unground precooked rice was mixed with the binder and hand formed into large size (1-1/2 x 3 x 1/2 in.) blocks. The large die used to form the blocks is described in the Appendix. These blocks, after drying, were strong and very hard. Blocks similarly prepared with the 1:1 milk binder and 3/8 in. pieces of prefried bacon were also strong and hard after drying. These experiments indicated that milk pastes containing approximately one part dry milk and one part water were good adhesives. This exploratory work became the basis for the wet binder method. The general procedure used in the wet binder method was to mix binder paste with the bacon and rice.

Blocks of the mixture were then hand formed into molds, removed and air-dried at temperatures varying from 100 to 120°F.

### 3. Effect of Pretreatment, Ground Rice

The effect of several processing variables in the wet binder method was studied. The binder paste in all cases was a 1:1 mixture of dry milk and water.

The effect of pretreatment of the rice was studied. The rice was pretreated as follows: 1. No pretreatment. 2. Adjusted to 30 percent moisture. 3. Held 2 hr. with bacon at room temperature. 4. Held 2 hr. with bacon at 140°F. 5. Mixed by hand with bacon for 5 min. Ground bacon (1/4 x 1/4 in.), coarsely ground rice (16 - 20 mesh), and binder were made up according to the basic test block formula and mixed without mashing for about 2 min. Twelve gram portions of the mixture, equivalent to about 10 g. of the original dry materials, were worked by hand into the small die, which was used as a mold. The formed blocks were removed from the mold and dried for 16 hr. at 100°F. This drying removed the water added in the binder. The blocks were tested for breaking strength. They were also tested for shattering by being dropped from a height of 10 ft. to a concrete floor, as described in the Appendix under "Drop Test."

The results are presented in Table II. The blocks made with untreated rice showed a breaking strength of from 4 - 6 lb., which was increased to a range of 7 - 9 lb. when the rice was adjusted to 30 percent moisture. Breaking strength was further increased to a range of 7 - 12 lb. when the rice was soaked with the bacon fat. Blocks made with the rice soaked in this way did not break when dropped from 10 ft., whereas three blocks out of five broke when the rice was untreated. Soaking the rice in bacon fat strengthened the blocks. Table II also shows no advantage was obtained from increasing the steeping temperature from room to 140°F.

### 4. Effect of Pretreatment, Whole Rice

The procedures used in the round rice study were modified by using 3/8 in. bacon pieces and unground rice. The results are shown in Table III.

The breaking strength of blocks made with the pretreated rice was higher than with untreated. A breaking strength of more than 18 lb. was obtained, and the blocks appeared to be thoroughly consolidated. The blocks were easily bitten off and chewed, and they had a bacon flavor.

5. Effect of Sizing Rice

The effect of sizing the rice with adhesive was tested. In these experiments, both large and small blocks were made. Control blocks were made by mixing 1:1 milk binder with the bacon and rice, without treatment of the rice. The three components were mixed and formed into blocks in the steel die by pressing the mixture in by hand. The blocks were removed and dried at 100°F. Rice in the experimental blocks was sized with a small quantity of extra milk. The extra milk was made up in a solution containing one part dry milk plus two parts water. The rice was mixed in this solution for 2 min., held for 10 min., remixed, removed, and air dried at room temperature. Preparation of the blocks was then completed in the same manner as with the controls. The hardness and smoothness of the blocks were increased by sizing the rice.

The physical characteristics of the smaller blocks closely reflected those of the larger ones. A small block with a breaking strength of more than about 10 or 12 lb. did not break when dropped on the floor from a 10-ft. height. In general, the large blocks would pass the 10-ft. drop test whenever the smaller blocks would pass it. On this basis, the correlation in the physical properties between the large and small blocks appeared sufficient so that most of the work could be continued using the small blocks.

6. Effect of Holding Time

The effect of holding time after mixing and before hand-molding the basic test formula was examined. Stronger blocks were obtained when the mixed ingredients were molded within 15 min., rather than holding the mixture 3 hr. before molding. The longer holding period produced rougher looking blocks with lower breaking strength than blocks formed after the short holding period.

7. Effect of Aging

Blocks made under the basic test block formula, as well as a number of variations of this formula, deformed under 5 psi pressure at 100°F for 24 hr. Vertical shrinkage or lateral expansion in excess of 10 per-cent was considered excessive. Preliminary results indicated that aging would increase the resistance to deformation.

To test this possibility, two series of test blocks were prepared. One series used a 1:1 mixture of dry milk and water as a binder. The other series used a 2:7 mixture of sodium caseinate and water as a binder. Small blocks were hand formed and dried to 20 - 25 per-cent moisture. The moisture content, breaking strength, and 100° deformation was determined immediately after drying on representative samples of the blocks. Other samples of the blocks were wrapped in foil immediately after drying and stored on the laboratory bench for periods of up to 14 days. Breaking strength and deformation tests were determined after storage. The deformation test is described in the Appendix.

The results are summarized in Table IV. In the dry milk series, the breaking strength increased steadily up to a period of 10 days of storage. The samples then became extremely moldy, which probably accounted for a slight decline in the breaking strength. After aging for 3 days or more, the amount of deformation decreased to less than half that exhibited by the unaged samples. In the sodium caseinate series it was not possible to tell whether the breaking strength was improved by aging. The test blocks were very plastic and did not break when compressed on the breaking strength tester. Deformation was slightly increased after 3 days of storage. The test showed that aging definitely improved the strength of high moisture blocks made with dry milk, but was inconclusive for those made with sodium caseinate.

8. Additives to the Nonfat Milk Solids Binder

Several additives and replacements for the milk in the binder were tested in order to produce blocks which better fulfilled the required specifications.

a. Instant cornstarch: One of the most extensively tested replacements for milk binder was instant cornstarch (National 78-1215). At first, 25 per-cent of the milk in the basic test formula was replaced

with this starch. Small test blocks were hand formed as previously described, using unground rice which had been steeped for 2 hr. at room temperature with 3/8 in. bacon. The addition of starch required more water in the binder paste. Therefore, the amount of water used for making the binder paste was doubled. Instead of a 1:1 ratio, a 1:2 ratio of solid to water was used. The finished blocks had a lower breaking strength but the surface was smoother than that of blocks bound with straight milk.

Another series of blocks was prepared with a binder consisting of 80 per-cent dry milk and 20 per-cent instant cornstarch. Binder pastes were made up with from 20 - 50 g. of water/20 g. of dry binder ingredients. The finished blocks were dried to differing moisture contents at 100°F and breaking strength values were determined. Results are shown in Table V. The results indicated that starch could be used in the milk binder when the binder must withstand moisture contents as high as 25 per-cent in the blocks.

Another series of test blocks was prepared by the same procedure, but a binder consisting of 90 per-cent nonfat milk solids and 10 per-cent instant cornstarch was used. Batches consisting of 100 g. of the block ingredients were made, using from 20 - 40 g. of water for the 20 g. of binder mixture. The blocks were dried for 16 hr. at 110°F. Breaking strength and 10-ft. drop loss were determined on the dried blocks. The results are reported in Table VI. Increased breaking strength and decreased 10-ft. drop loss were shown when the initial water for making up the binder paste was increased. Higher moisture levels for the binder paste reduced the viscosity, making better adhesion possible.

The effect of final moisture in test blocks made with 10 per-cent instant starch binder was checked. All blocks were made with a binder paste consisting of 20 g. of dry binder ingredients and 30 g. of water and were dried to differing moisture levels. The physical data obtained on these blocks are shown in Table VII. The breaking strength of the blocks approached the satisfactory figure of 10 lb. at a final block moisture value of 25 per-cent, and increased to 15 lb. in the drier blocks.

Later, an attempt was made to shorten the drying time for the starch binder blocks by raising the drying temperature to 160°F. A series of small test blocks was prepared using 30 g. of water to 20 g. of dry binder mixture. The blocks were dried 16 hr. at 160°F.

These blocks had an average moisture content of 10.3 per-cent and an average breaking strength of 22 lb., which was very high. The 10-ft. drop loss averaged 1.8 per cent. Although the efficiency of drying was increased by raising the drying temperature, the blocks browned slightly due to the heat.

The value of starch in improving the resistance of the binder to high moisture was established in the above experiments. However, the slow drying characteristic imparted by this type binder was felt to be undesirable.

b. Cerelose: Cerelose was tested as a replacement for milk. The cerelose was introduced at a level of 25 per-cent of the binder solids. The binder paste was made by the addition of 20 g. of water to 15 g. of nonfat milk solids and 5 g. of cerelose. The test blocks were dried 16 hr. at 100°F. A good breaking strength of 12.2 lb. was obtained in the finished blocks. They were, however, slightly sticky.

Cerelose was then added to the milk in the binder mixture rather than replacing a portion of the milk. The same general procedure for forming blocks was used as before, and the results obtained are shown in Table VIII. Cerelose tended to raise the breaking strength of the blocks if extra water was added along with it, and, in most cases, blocks made with cerelose showed less drop loss than those made with straight milk binder.

Cerelose was then added on a direct replacement basis for the milk at levels of from 25 - 100 per-cent of the total binder. A 1:1 water level was used in all cases and the previously outlined procedure was followed. The results, which are shown in Table IX, indicate that whereas small percentages of cerelose in the binder had strengthened the blocks, larger percentages produced a progressive decrease in strength, with a corresponding increase in drop loss. Cerelose decreased the viscosity of the binder and also decreased its tendency to set up hard on drying. All blocks were dried to the approximate moisture content of the ingredients, not including the added water in the binder (9.5 per-cent), but it was believed that they would have been still stronger if the moisture content had been reduced below this figure.

c. Lecithin: A third material tested at a 25 per-cent level was lecithin. The same procedure was used as with the starch and cerelose. In making up the binder paste, 15 g. of nonfat dry milk and 20 g. of water were mixed, and 5 g. of lecithin was then beaten into this thick paste. The blocks obtained with this binder had a breaking strength of 7.6 lb., which was slightly lower than that for a straight milk binder. They were also more plastic and oily than with the straight milk binder. The value of lecithin was, therefore, demonstrated in cases where excessive hardness must be avoided.

d. Gelatin: Low viscosity gelatin was also tested at a 25 per-cent level in the milk binder. Twenty grams of water were required for 20 g. of the dry binder ingredients, and the binder paste was applied to the blocks while warm. The finished blocks were unusually firm and had a high breaking strength of 16.1 lb. Gelatin, therefore, appeared to be a useful binding ingredient. Further experiments with gelatin hot melts are described in a later section.

e. Raw cornstarch and wheat flour: Several unsuccessful attempts to improve the strength of the test blocks were made by incorporating raw cornstarch or wheat flour and cooking after the blocks were formed. In the first attempt, the binder mixture consisted of 70 per-cent nonfat dry milk, 10 per-cent instant cornstarch and 20 per cent uncooked cornstarch. The usual procedure for making up the blocks was followed, using 30 g. of water for each 20 g. of dry binder ingredients. The formed test blocks were wrapped in foil and cooked for 1/2 hr. at 130°F. The dried blocks showed a satisfactory 10-ft. drop test, but their resistance to deformation was no greater than that of test blocks made with straight milk binder.

In a second exploratory experiment, the above experiment was repeated, using wheat flour instead of raw cornstarch. The same results were obtained. The test was repeated in a third exploratory series with a binder consisting of 60 per-cent dry milk, 10 per-cent instant starch, 20 per-cent wheat flour and 10 per-cent low viscosity gelatin. Again the changed formulation of the binder produced no improvement in resistance of the blocks to deformation.

In a fourth series, binder mixtures containing from 10 - 80 per-cent of uncooked cornstarch, with the balance of the mixture as nonfat milk, were used in preparing test blocks by the usual procedure. The blocks were wrapped in foil and cooked for 1/2 hr. at 180°F. Examination

of the dried blocks showed that those made with 10 per-cent raw starch binder were stronger and tougher than controls made with 10 per-cent instant starch. However, higher levels of raw starch produced test blocks which were progressively weaker than the controls, and at the 80 per-cent raw starch level the blocks fell apart.

The results indicated that, although resistance to deformation at high moisture was increased by small levels of instant starch, cooking higher levels of raw starch in the blocks was not beneficial.

The above series was repeated essentially as before with the blocks dried to 14 - 16 per-cent and 8 - 12 per-cent moisture. The results obtained in this repeat series are shown in Table X. Test blocks made with raw starch at a 20 per-cent level in the binder showed slightly less deformation, and as good a breaking strength as a control made with 10 per-cent instant starch. Higher levels of raw starch, however, had a weakening effect on the blocks.

Further tests on binders cooked after the blocks were formed were run with wheat flour. The wheat flour replaced 10 - 80 per-cent of the nonfat dry milk in the basic test formula binders. The blocks were dried in two moisture levels, and were tested for deformation and breaking strength. As shown in Table XI, none of the binders containing flour improved the strength of the blocks at either of the moisture levels to which they were dried. Depending upon the amount of flour used in the binder, the blocks were either elastic and rubbery, or were crumbly and fell apart.

To test the effect of stiffer flour mixtures, the test block formula was made up with the nonfat dry milk completely replaced with flour. For the 20 g. of flour used for the formula, levels of from 10 - 30 g. of water were used for making up the binder pastes. The bacon and rice were mixed with the pastes, and small test blocks were formed in the usual way. The blocks were baked for 40 min. at 200°F and were dried to 11 - 14 per-cent moisture. As shown in Table XII, the breaking strengths were less than those usually obtained with 10 per-cent instant starch and dry milk. The deformation values were also greater. The thicker doughs produced slightly stronger blocks than those made with the higher levels of water, but even the best blocks tended to be rubbery and elastic, rather than hard or brittle like those made with the regular binder.

The idea of obtaining strength with raw starch and flour by cooking them in the finished blocks, therefore, did not appear promising.

f. Sodium caseinate: Sodium caseinate was tested as a binder. The test block formula was prepared in the usual way, with sodium caseinate entirely replacing the nonfat dry milk. The binders were made up with from 30 - 60 g. of water for 20 g. of sodium caseinate. An additional series was made with a binder consisting of 16 g. of sodium caseinate, 4 g. of lactose, and 50 g. of water. The blocks were dried for 16 hr. at 110°F. The results of the tests performed on the blocks are shown in Table XIII. The finished blocks were very strong, but were tougher and less brittle in character than control blocks made with a milk-starch binder. The breaking strengths were all higher than that of the control blocks and they tended to increase with the level of water in the binder and in the finished blocks. The sample made with lactose was harder than any of the other experimental samples. Lactose was, therefore, believed to be the material in milk which contributed to the hard and brittle character of blocks made with a milk binder.

A second sodium caseinate series was run in the same manner as above, except that slightly higher levels of water were used in the binder pastes. Drying of the blocks was carried further than previously. As seen in Table XIV, the sodium caseinate blocks were definitely harder, and less elastic than the control after this more thorough drying. Breaking strengths were greatly increased and deformation at 100°F was essentially prevented.

This and the preceding run with sodium caseinate showed that the protein in milk was the active adhesive material, but that carbohydrate such as lactose was needed to contribute hardness at higher moisture levels.

g. Dried egg albumen: An additional protein binder, spray-process dried egg albumen, was evaluated. Several water levels for the adhesive paste were used, and blocks were prepared by the procedure used above. An uncooked series was made by drying the formed blocks at 110°F. A cooked series was prepared in which all samples except the milk control were baked for 20 min. at 200°F in a covered pan. The results of these tests are shown in Table XV. Albumen in the uncooked series showed slightly lower breaking strengths, but definitely less deformation than nonfat milk. The results in the cooked series showed similar deformation characteristics but higher breaking strengths than the uncooked series.

As both sodium caseinate and egg albumen were shown to be stronger binders than nonfat milk, interesting possibilities were demonstrated for protein adhesives. Egg albumen was later selected as the binder for preparation of the prototype blocks.

## B. Preparation of Prefried Bacon, Rice, and Milk Test Blocks by Procedures Other Than Wet Binding

### 1. Conventional Tableting Method

Several possibilities for forming blocks other than the use of the wet binder method were suggested by our work. One of these was that a coating of dusting material might make it possible to subject the particles of bacon to the pressures of conventional tableting without excessive loss of fat. Another possibility was to coat the bacon with an adhesive surface-hardening agent. Our exploration of these approaches is reported below.

a. Dusting the bacon: Prefried bacon in both the ground (1/4 x 1/4 in.) and piece (3/8 x 3/8 in.) forms was mixed with flour at the rate of 15 g/50 g of bacon. The bacon took up the flour almost completely. The coated bacon was mixed with 10 g. of whole instant rice, 15 g. of nonfat milk solids, and 10 g. of medium fine ground crystalline sorbitol. The completed mixture was compressed into small size blocks at total jack pressures of 3,000 and 5,000 lb.. Fairly well consolidated blocks showing 10-ft. drop losses of from 10 - 25 per-cent were obtained. The breaking strengths were only 1 - 2 lb., indicating very weak blocks.

The experiment indicated that with dusting, considerably more tableting pressure could be applied than when using nondusted bacon.

Attempts were made to learn how much the strength of test blocks could be improved by dusting the bacon. The basic test block formula was modified as follows: 50 per-cent prefried bacon, 15 per-cent unground precooked rice, 15 per-cent dusting material and 20 per-cent nonfat dry milk solids, or other fine ground material. Both ground and piece forms of bacon were used. The bacon was mixed with the dusting material in a Hobart mixer for 30 sec. at low speed. The binding material was then added and the mixing continued for another 30 sec. Ten gram portions of the complete mixture were then compressed into small

test blocks using a minimum dwell time of 3-5 sec. and jack pressures of 2,000 - 5,000 lb. The finished blocks were tested for breaking strengths and drop loss, and were examined for relative amounts of delamination.

Table XVI shows the various combinations of dusting and binding materials which were used and the tableting pressures which were applied. The nondusted control formed laminated blocks which delaminated easily. Delamination was definitely decreased in many of the preparations made with dusted bacon. In the control there was excessive fat loss under a total jack pressure of 2,000 lb. Considerably higher pressures could be obtained in many of the dusted bacon formulas. Dusting the bacon tended to improve the breaking strength of the blocks. The use of dusting and binding materials which would become sticky upon the addition of small quantities of water was superior to that of materials of a dryer type. None of the blocks approached the desired specifications. However, the combinations of materials tested appeared to be good starting points for the addition of small quantities of moisture, granular or other specially shaped particles, or for the tableting of a partially defatted bacon.

In a further experiment using the above procedure, fine ground Frodex was used as a dust and dry nonfat milk solids as a binder. Blocks tableted at a total jack pressure of 2,000 lb. showed breaking strengths of 8.1 and 5.1 lb. for the ground and 3/8 in. bacon pieces, respectively. Drop losses for the two types of bacon, in the same order, were 2 and 4 per cent. This latter combination of dusting and binding materials was, therefore, one of the better ones tested.

b. Coating the bacon: A promising material for coating the bacon for high pressure tableting of the test block formula was a 70 per-cent sorbitol solution, Sorbo.

Fifty grams of 3/8 in. bacon and 20 g. of Sorbo were mixed and the coated bacon was dried for 2 hr. at 100°F. The dried pieces of bacon were stiff, but plastic and sticky after standing in the laboratory for 24 hr. Fifty grams of the coated bacon were mixed with 30 g. of whole precooked rice, 18 g. of dry nonfat milk and 2 g. of ground crystalline sorbitol. The mixture was tableted into small test blocks.

As shown in Table XVII, the blocks had breaking strengths ranging from 2 - 9 lb.; an improvement over test blocks made with either untreated or dusted bacon.

The addition of a small amount of water to the uncompressed materials yielded test blocks with increased breaking strength when the blocks were made with larger cuts of bacon. The experiment was repeated with 1/4 in. instead of 3/8 in. bacon and the results are again shown in Table XVII. Added water decreased rather than increased the strength of the blocks made with the finer cut of bacon.

The 3/8 in. bacon was partially defatted by warming at 120°F and draining off the free fat. Fifty grams of the partially defatted bacon were coated with Sorbo syrup in the same manner as previously described. The rice to be added to the coated bacon was premoistened by adding 7 g. of water to 30 g. of whole rice and tempering for 1 hr. Fifty grams of the coated bacon were mixed with 37 g. of the moistened rice, 16 g. of nonfat dry milk and 4 g. of crystalline sorbitol. The mixture was tempered for 1 hr. and then tableted at pressures up to 2,000 lb. Greater jack pressures than 2,000 lb. resulted in extrusion of the material from the slightly wet batch. The compressed blocks were dried for 3 hr. at 100°F.

The finished blocks were very strong. The average breaking strength was 15.8 lb. Part of the moist mixture was dried for 15 min. at 100° before tableting. The tablets made from the dried mixture had a slightly lower breaking strength than those made from the wet mixture and subsequently dried. The results are reported in Table XVII.

Fifty grams of 3/8 in. bacon were coated by first mixing with 10 g. of Sorbo syrup and then mixing with 18 g. of nonfat dry milk. In a separate container, 30 g. of whole rice were mixed with 5 g. of water and subsequently with 2 g. of crystalline sorbitol. The three-component mixture was tempered for 15 min. The coated bacon was then mixed with the coated rice and the mixture of the two dried for 1/2 hr. at 120°F. The dried mixture was compressed warm at 2,000 and 4,000 lb.

Results are summarized in Table XVII as Series 3. Very strong blocks with breaking strengths of 30.6 and 40.0 lb. were obtained. The breaking strength was only 9.0 lb. when the uncompressed mixture was held in the refrigerator for 1/2 hr. before tableting even though 5,000 lb. pressure was used.

This series of experiments showed that a real advantage was to be obtained by coating bacon with Sorbo syrup and then drying. The coating increased the strength of the test blocks and decreased the amount

of fat leakage from the bacon. Some of the blocks were as strong as those made by the wet binder method. Therefore, the Sorbo coating procedure could probably be developed for making prototype blocks. However, a considerable amount of art is involved in this procedure. Probably, a number of specific modifications would be needed for each prototype food formulation.

It proved to be difficult to apply other sticky coating materials such as gelatin, egg albumen, or starch to individual particles of the 3/8 in. bacon. Materials which would stick to the bacon usually stuck with greater tenacity to any support, such as a screen, used when they were dried. In spite of this difficulty, we showed that the bacon particles could be coated individually with a layer of gelatin, which adhered well but became hard and brittle when dry. Similar results were obtained with coatings of beeswax.

2. Hot-Melt Adhesives

A more promising procedure was to handle the bacon pieces unseparated, using an adhesive coating which was liquid when hot, and which set up solidly on cooling, but did not require subsequent drying. The latter property implied a high solids content, with only very small amounts of water for dispersion. An exploratory search for such "hot melt" adhesives was carried out.

Melted beeswax was unsatisfactory for building up the concentration of a 20 per-cent solution of high strength gelatin, since it was immiscible with the gelatin solution when melted and formed a grainy, sticky mixture on cooling and mixing. A somewhat smoother, but extremely sticky preparation, was obtained when the experiment was repeated with Myrj 52 instead of the beeswax.

Highly soluble carbohydrates were found to be valuable for building up the solids content of gelatin hot melts. In preliminary experiments it was possible to double the solids content of a 20 percent suspension of high strength gelatin by adding cerelose or Frodex 24.

The use of gelatin of lower viscosity (Swift's Centura) permitted higher concentrations of gelatin in the hot melts. A mixture of 8 g. of this gelatin with 10 g. of water was not too viscous for use as adhesive when warmed to 120°. As a single ingredient for a hot melt,

Frodex 24 made a good adhesive at concentrations of up to 80 per-cent and sorbitol could be handled at concentrations of up to 90 per-cent and higher. Such ingredients were considered useful for hot melts because they would require little or no drying after the blocks were formed.

The effect of stepwise addition of cerelose to Centura hot melts was tested. Eight grams of Centura gelatin were mixed with 4 - 6 g. of cerelose in 400 ml. beakers. Ten grams of water were added to each beaker and the contents stirred. Very thick, nonfluid mixtures resulted. The beakers were covered with watch glasses and the contents warmed on a steam bath. This caused the semisolid mixtures to melt down into thick viscous suspensions, all materials dispersing completely. The batch in each beaker was then restored to the original weight by the addition of a little water, covered tightly, and allowed to stand at room temperature for 24 hr.

Subjective observations made on the warm and cool melts are summarized in Table XVIII. Very adhesive hot melts were made, which contained up to nearly 70 per-cent solids. The effect of increasing cerelose in the series was to slightly decrease the viscosity of the melts when warm. Firmness of the blocks of cooled adhesive decreased slightly and their stickiness increased slightly with increasing concentrations of cerelose.

The use of Centura-cerelose hot melt adhesives was tested with the test block formula. Twenty-five grams of 3/8 in. bacon and 15 g. of whole rice were mixed in a beaker. Adhesive mixture C-1 (see Table XVIII) was then warmed up to about 140°, and 18 g. of it poured over the mixture of bacon and rice. This provided approximately the same proportion of adhesives on an original ingredients basis as in the basic test block formula. The warm adhesive spread rapidly over the bacon and rice, and adhered well. After stirring the mixture for a few seconds, small blocks were formed by pressing it in the steel mold. The adhesive set up rapidly. Only four blocks could be formed before the mixture became too stiff to handle. The finished blocks had a good appearance, very much like that of the test blocks made by the wet adhesive method.

A second trial with test block formula was run using the procedure as above, with the exception that C-2 adhesive was used instead of C-1. Also, the adhesive was warmed in the beaker and the bacon and rice then mixed in the warm beaker containing the adhesive. An adverse effect was noted from mixing the 3/8 in. bacon in a warm environment, in that it leaked large quantities of fat. The rice in this case was ground medium fine and warmed with the adhesive formula C-2. The bacon was added to

the warm adhesive and rice. This procedure resulted in severe oil loss from the bacon.

In a subsequent run, the adhesive was poured over the mixture of bacon and rice. Ten grams of 3/8 in. bacon and 6 g. of whole rice were mixed lightly in a 100 ml. beaker and lightly tamped down to approximately minimum volume. Fifteen grams of melted C-3 adhesive was poured over the tamped mixture. The melted adhesive ran down into the spaces of the blocks easily, filling the voids almost completely. The pour technique, therefore, appeared to be a very good method of applying hot melts. Solid well-filled blocks were formed. However, they contained a larger percentage of adhesive than did the original basic test formula.

Table XIX summarizes the notes made on the appearance and the physical data obtained on the blocks formed in the above four experiments. The blocks, in general, were strong and rubbery, and they tended to return to the original form after compression. It is believed that blocks such as these could be made to meet the Quartermaster Corps requirements. The elasticity could be overcome by drying them slightly.

The findings in the above experiments would be true generally for any hot melt formulas prepared from low viscosity gelatin plus highly soluble carbohydrate. Evidence suggested that melted adhesives of this type could be used in a very simple and rapid block-forming operation, particularly in that drying of the formed blocks would be minimized or eliminated entirely. Although manipulation of the melted adhesives was difficult in the laboratory, it would probably lend itself easily to production on continuous equipment. The importance of avoiding, as much as possible, mixing of the bacon in the presence of hot melt was emphasized. The procedure of pouring the melted adhesive over the bacon and rice had the advantage that the bacon received no agitation.

Additional tests were needed to establish roughly quantitative relationships between the viscosity of the hot melt, the amount of hot melt used, and the pore size of the block. Preliminary experiments indicated that the viscosity of the melt could not exceed a certain maximum with each pore size in the block. It was also obvious that smaller quantities of adhesive would be needed if the size and number of voids in the block were small.

In further experiments, the precooked rice used for preparing the test blocks was handled either ground or unground. The ground was

screened to either 10 - 14 mesh or 16 - 20 mesh. Stock hot melt adhesive was made up containing 50 g. of high strength gelatin, 50 g. of cerelose and 100 g. of water. Penetration tests were run using this stock adhesive on test blocks made with the above three sizes of rice. In these tests the stock gelatin-cerelose adhesive was used as is and diluted with two levels of water. Each adhesive suspension was warmed to 140°F and the viscosity was determined using a Brookfield viscosimeter (see Appendix section on equipment). For each concentration of adhesive tested, three 50 ml. beakers were set up, each containing 5 g. of 3/8 in. bacon and 3 g. of rice, tamped down gently to minimum volume. The rice in the first beaker was unground; that in the second, medium ground; and that in the third, fine ground to the screen sizes mentioned above. A slight excess of adhesive at 140°F was poured over the surface of the materials in each beaker. The blocks were then observed to determine whether the penetration of the adhesive was negative, partial, or complete.

The next step in the above quantitative test on pour-on adhesives was to learn approximately the minimum amount of adhesive required to fill all of the spaces in the three types of blocks. A dilute solution of the stock adhesive which would completely penetrate all blocks was used. Fifty millimeter beakers containing pieces of bacon and the three grinds of rice were again prepared. Increasing amounts of the hot adhesive were poured over the block in each beaker until the amount applied was just sufficient to wet or cover the entire mass of bacon and rice. The amount of adhesive in each case was noted.

The third step in the quantitative tests was to determine the bulk density of the tamped bacon and rice mixtures used. This was done by tamping the mixtures in 250 ml. graduate cylinders and noting the volume.

The results obtained from these three tests are consolidated in Table XX. They indicated that it was possible to obtain complete penetration with fairly viscous hot melts as long as the blocks had an open structure. The percentages of adhesives used were somewhat higher than in the regular test formula used with the wet binder.

The experiments confirmed the practicality of the pour-on method for using hot melts both with and without a final drying step.

In later exploratory experiments, we attempted to use melted fat as a pour-on adhesive. This material was not applicable as it did not stick to the bacon, and, also, hardened so rapidly that penetration was not

complete. In a further exploratory test, the strength of the crumbly fine-textured blocks was somewhat increased by soaking the blocks in a solution of zein in 70 per-cent alcohol and, subsequently, drying.

## C. Development of Prototype Ration Blocks by Means of the Wet Binder Process

The wet adhesive procedure, using relatively high levels of edible binders such as nonfat dry milk, sodium caseinate, or egg albumen, appeared to be suitable for making prototype blocks of suitable quality for shipment to the Quartermaster Corps. A series of ration block formulas was, therefore, developed for the above purpose and the development is described below.

### 1. B-1 Bacon

The first ration developed was of a meat type, based on the basic test block formula. The new formula, which was also based on bacon and rice, was designated B-1 and first consisted of four parts prefried bacon, two parts precooked rice, and two parts of dry binder. The nonfat dry milk binder in the basic test formula was replaced with egg albumen. This material was more easily dried than the nonfat milk and it was expected to be more stable on prolonged storage.

In the first run of Formula B-1, a procedure was used which became general for the preparation of prototype blocks. The dry albumen was well mixed with room temperature tap water until all lumps were dispersed. The resulting paste was covered and held overnight in the refrigerator and then remixed before using. The egg albumen paste in the first run of Formula B-1 contained 25 g. of water to 20 g. of dry albumen. The bacon and rice were mixed but not steeped, and immediately mixed with the binder paste. Blocks were immediately formed in the steel molds and then dried in a circulating warm air dryer. In the first run of Formula B-1, the blocks were of the small size and were dried for several experimental periods at 110° and 120°F.

The physical properties of the B-1 blocks obtained in the first run were satisfactory, but the drying conditions were not properly

adjusted. A second series of B-1 blocks were, therefore, prepared using the following slightly modified formula which provided additional calories: 45 per-cent prefried bacon, 35 per-cent precooked rice, and 20 per-cent egg albumen binder. The above general procedure was used, but 20 g. of water was used for each 20 g. of dry albumen. Drying conditions for the blocks were again subject to experimental variation. The properties of the finished blocks suggested that Formula B-1 should be dried for 16 hr. at 120°F. This drying condition and the formula in second run of B-1 became the standard for this type of ration block and was used to prepare the food blocks sent to the sponsor.

Large blocks made by the above formula and procedure showed a 10-ft. drop loss of 2 per-cent and a moisture content of 6.6 per cent. Evaluation of this and other prototype blocks is described in a following section on evaluations and is summarized in Table XXIII. The second prototype ration formula was B-2, chicken.

2. B-2 Chicken

Formula B-2 consisted of 50 per-cent precooked, freeze-dehydrated chicken pieces, 18 per-cent coarsely ground survival ration crackers, 12 per cent hydrogenated coconut fat and 20 per-cent egg albumen binder.

A satisfactory product was produced in the following manner. The fat was melted, mixed with the crackers, and this mixture was allowed to cool. It was then mixed with the chicken and, subsequently, with the binder paste, which had been made up with a level of 25 g. of water for 20 g. of dry egg albumen. More consolidation than was possible with hand forming was needed to obtain the proper density in the blocks. Small size blocks were, therefore, compressed at a total jack pressure of 1,000 lb. and dried for 16 hr. at 120°F.

Large blocks of Formula B-2 prepared by the above procedure did not shatter, but broke in half when dropped from 10 ft. on the cement floor. Experience with various additives for the wet binder, discussed in Section A, suggested brittleness could be modified by further formulation.

3. B-3 Beef

The third meat prototype ration was B-3 beef. The block formula consisted of 50 per-cent dried beef, 30 per cent coarsely ground survival crackers, and 20 per cent egg albumen binder. Binder paste was made up with 25 g. of water for each 20 g. of dried egg albumen. Both small and large size blocks were formed under a jack pressure of 1,000 lb. and dried for 16 hr. at 120°F.

4. C-3 Soy Cracker

Two cereal ration formulas were tried and were not considered satisfactory for prototype blocks. The first was C-1, which contained 60 per cent soybean grits, 20 per cent hydrogenated coconut oil, and 20 per cent egg albumen binder. The second formula, C-2, consisted of 60 per cent coarsely ground survival crackers, 20 per-cent hydrogenated coconut oil and 20 per-cent egg albumen binder. Although the physical properties of the blocks prepared by these two formulas were satisfactory, they were not felt to contain a broad enough variety of cereal protein.

Formula C-3 was considered more satisfactory from a nutritional standpoint than the above two formulas, and was used for prototype ration blocks. C-3 contained 30 per-cent soy grits, 30 per cent coarsely ground survival cracker, 20 per-cent 98° hydrogenated coconut fat, and 20 per-cent egg albumen binder. Twenty grams of water were used for each 20 g. of dried egg albumen in the binder. The mixture of soy grits and crackers were soaked in the melted fat. The cereal and fat mixture was then cooled, mixed with the binder paste and formed into blocks by hand. The blocks were dried for 16 hr. at 120°F. A later modification of C-3, which improved the density, consisted of compressing the blocks under a total jack pressure of 1,000 lb. Three-inch blocks, made using this modified procedure, broke into large pieces under a 10-ft. drop but did not shatter.

5. D-1 Peanuts

Two types of dessert formulas were made up in the form of prototype blocks. The first of these was Formula D-1, peanuts. The formula consisted of 50 per-cent coarsely-ground dry-roasted peanuts,

30 per cent precooked rice, and 20 per cent egg albumen binder. The usual general procedure was followed, using 25 g. of water for each 20 g. of dry egg albumen binder. The blocks were hand formed and were dried for 16 hr. at 100°F.

6. D-2 Coconut

The second dessert ration formula was D-2, coconut. The formula consisted of 50 per-cent shredded coconut, 30 per-cent whole precooked rice, and 20 per-cent egg albumen. Following the usual procedure, the binder paste was made up with 25 g. of water for 20 g. of dry albumen and blocks were hand formed. The blocks were dried for 16 hr. at 100°F.

An interesting formula D-3 was tried experimentally but was not shipped as a prototype block, since the principal starting material was not readily available. The formula consisted of 60 per cent expeller process defatted peanut meal, 20 per-cent hydrogenated coconut fat and 20 per-cent egg albumen. As prepared by the general procedure described above, this formula produced blocks with a dark brown color and a slightly heavy but interesting flavor, unexpectedly suggestive of meat. The blocks could be bitten off and chewed in a satisfactory manner.

Information relating to the six prototype formulas which were shipped to the sponsor is summarized in four tables in the Appendix. Table XXI reviews the formulas and calculated analyses; Table XXII shows points in the general procedure which were modified specifically for each formula; Table XXIII summarizes acceptability data, and Table XXIV summarizes the physical test data which were obtained on the freshly prepared, and on the stored, prototype blocks.

## D. Storage Test on Prototype Ration Blocks

The prototype blocks should withstand three months storage at 100°F. A new series of each of the six previously listed prototype formulas was prepared for accelerated storage, and procedures outlined. For the storage tests, 200 g. batches of each formula were made up in the small size blocks. For storage, the blocks from each formula were

divided among two 8-oz. glass jars. The jars were fitted with rubber stoppers, the inner surface of each of which was lined with aluminum foil in order to prevent odor absorption from the stopper. The stoppers were fitted with glass tubing inlets and outlets which permitted the contents of the jars to be swept with nitrogen.

The stoppers were applied to the jars tightly, and the outer seams sealed with beeswax. Air was exhausted from the jars by pulling a full vacuum with a water aspirator. The vacuum was released by running in USP nitrogen. The exhausting and gassing with nitrogen were then repeated twice more. With the bottles at atmospheric pressure, the gas connections were sealed and one bottle of each formula was then placed in a constant temperature cabinet at 100° ± 1°F. The other bottle of each formula was placed in a 0°F freezer. The second bottle served as a reference for taste testing the samples at the end of the warm temperature storage.

At the end of the three-month storage period, the 100°F and 0°F samples were examined by the laboratory personnel for color, odor, bite characteristics, and flavor. Although not formally taste-tested, they were given 1 - 10 hedonic ratings, which reflected the opinion of the laboratory workers on their odor and flavor. The blocks which had been stored at 100°F as well as at 0°F were tested for breaking strength, 10-ft. drop loss, and vertical and lateral deformation at 100°F. These tests were run in exactly the same way as on the fresh samples prior to accelerated storage.

Table XXIII summarizes the notes made on the examination for acceptability of the 0° and 100°F stored samples. The chief change in the appearance of the 100° blocks were a slight yellowing and the development of mild toasted odors and flavors. Since the ingredients used all had a stability considerably greater than that required in the test, the color and flavor changes were probably due to the binder.

In Table XXIV, the physical values obtained on the 100° stored samples are compared with those made on fresh preparations prior to the test. These data indicated that there were only minor changes in the physical values due to accelerated storage. The general conclusion was reached that accelerated storage had only a minor effect on the physical structure of the blocks made with wet adhesives.

Following the storage test, further batches of each of the above prototype formulas were prepared and shipped to the sponsor. The batch of each formula included a series of large blocks for shipment, and a series of small blocks for repeat determination of several of the physical values. The physical data obtained on the series for shipment are shown in Table XXV. In general, the values on the new blocks agreed closely with those on the series prepared before the three-months storage test. The shear strength and impact resistance figures (see Methods in Appendix A) suggested the following properties among the six formulas: 1. Bacon -- good chewing character, but possibly slightly fragile. 2. Chicken -- hard, at maximum toughness that can be chewed. 3. Beef -- firm, solid and strong, but satisfactorily chewable. 4. Soy-cracker -- easily chewable, but probably too fragile. 5. Peanut -- near maximum toughness for chewing, good impact resistance. 6. Coconut -- slight resistance to bite, but still brittle.

## E. Methodology and Testing of Food Blocks

The tests used in evaluating test block formulations have been mentioned in the preceding sections of this report. They will be outlined in detail in Appendix A. These tests on the finished block preparations indicated the moisture content, breaking strength, loss of material by fragmentation upon a 10-ft. drop, and the deformation under a steady load of 5 psi.

### 1. Breaking Strength and Drop Test

As applied to the best test blocks, the above tests indicated that the breaking strength averaged more than 10 lb. Such a figure corresponded to a block which was difficult to crush between the fingers. The blocks withstood a 10-ft. drop on a cement floor at room temperature and above. Both the strength and the resistance to drop loss held good even when the blocks contained up to about 25 per cent moisture. As noted below, however, the very moist blocks shattered when dropped at -65°F. There was also some difficulty in shattering with blocks dried to less than 10 per cent moisture, but it was felt that this could be overcome by adding a plasticizing agent such as lecithin. Special binder formulations were prepared which provided sufficient resistance to

deformation in the test blocks, even at 100°F and with a moisture content of over 20 per-cent.

The drop 65°F test will be described in detail in the Appendix. A block made with a nonfat dry milk binder containing 10 per-cent instant cornstarch was cooled to -65°F in a Dowanol-dry ice bath and dropped from a height of 10 ft. onto the concrete floor. Small blocks, containing from 17 - 26 per-cent moisture, showed essentially no breakage when dropped under these conditions. However, the same formula in the large size blocks showed breakage in 5 out of 6 blocks in the -65°F 10-ft. drop. The blocks broke into from 2 - 4 large pieces, rather than shattering completely. It was concluded that breakage of the large blocks at cold temperatures and high moisture content was a definite problem. It would appear possible to overcome it, however, either by adding a plasticizer to the binder, or by adding reinforcing fibers to the block formula.

Resistance of the test blocks to a 10-ft. drop at 100°F was also demonstrated. Small blocks were made by the standard procedure, with a formula containing 10 per cent instant cornstarch in the milk binder. They were dried to final moisture values ranging from 16.6 - 26.0 per-cent. The blocks were brought to a temperature of 100°F in a constant temperature cabinet and were dropped before having time to cool down appreciably. No breakage was noted and the only blocks which showed deformation were those that contained 26 per-cent moisture. This deformation was slight and was not considered objectionable.

Large blocks were prepared by the previous procedure and formula, and also tested for drop loss. A series with a moisture content of 18 per-cent was dropped through 10 ft. at a temperature of 100°F. No breakage appeared, but there were small cracks in one of the six blocks which were dropped. The test was repeated with blocks of the same size having a 31 per-cent moisture content. No breakage or cracks were noted, but there was a slight amount of deformation.

A 10-ft. drop loss test was performed on blocks dried in a vacuum oven to an average moisture content of 5.4 per-cent. On dropping these 10 ft. at room temperature, there was an average loss of 14 per-cent in weight, representing material broken off the edges. This figure compared with less than a one per-cent loss at the equilibrium moisture value of 10 to 11 per-cent. In another experiment large size test blocks were vacuum dried at 40°C to a moisture content of

3 per-cent. Upon dropping these blocks 10 ft. at room temperature, they shattered into many small pieces.

It was required that the test blocks retain their strength after being frozen and thawed three times. This effect was tested on a series of small blocks made with 10 per-cent instant starch binder and ranging from 17 - 26 per-cent in moisture content. These blocks were frozen three times in a 0° cabinet and thawed at room temperature. No breakage was seen in dropping them 10 ft. at room temperature. The breaking strengths ran only 1 - 5 per-cent lower than those for samples of the same blocks which had not been frozen and thawed. Additional large blocks, prepared by the same formula, were frozen and thawed in the same manner and subjected to 10-ft. drop tests at room temperature. There was a loss of 1.5 per-cent in blocks containing 25 per-cent moisture and 0.5 per-cent loss in blocks containing 19 per-cent moisture. These data indicated that there was essentially no deterioration in strength due to the three freeze thaw cycles.

2. Deformation

Specifications required the blocks to show less than 10 per-cent deformation in 24 hr. under a constant load of 5 psi. at temperatures of up to 100°F. The deformation test apparatus consisted of steel weights which were applied to the test blocks in a 100° cabinet. A detailed description of the apparatus and procedure is presented in Appendix A.

Deformation tests were run on a series of test blocks prepared using the regular formula and dried to three moisture levels. The blocks were compressed at room temperature, 40° and 100°F. As shown in Table XXVI, the resistance to deformation was good at 18 per-cent moisture, even in a 100°F environment. At 23 per-cent moisture, the resistance to deformation was just passable at room temperature and at 100°F it was excessive. Twenty-six per-cent moisture blocks deformed excessively, both at room temperature and 100°F, but not at 40°F. However, it has been noted in the preceding section that deformation in the test blocks could be overcome by special modification of the binder.

### 3. Shear Strength

A test for shear strength was required for evaluating the blocks made by the best binder methods. Shear strength values were obtained using a modification of the Warner-Bratzler meat tenderness tester. The procedure is described in Appendix A. The equipment pressed a flat bladed knife against the large surface of the block to be analyzed until the block sheared in half. The amount of pressure required to force the knife through the block was recorded as the shear strength. A number of different food materials were tested in order to develop figures with the methods which would reflect the difficulty of biting off and chewing. These were food blocks of various degrees of hardness prepared in the laboratory, dog biscuits, and sections from several firm vegetables of approximately the same size as the food blocks.

The data obtained in the initial trials of the shear test method are presented in Table XXVII. The shear strength method appeared capable of giving values which were consistent for food blocks of varying degrees of hardness and resistance to shear, which reflected the susceptibility of the foods to biting and chewing. The following interpretations for the ranges of numerical values were suggested for small size blocks as tested by the method: 0 - 10 lb. shear strength -- very soft, no effort to chew; 10 - 20 lb. shear strength -- quite definite shear resistance, but still no special effort required to bite off and chew, a range typical of most firm, solid food blocks; 20 - 30 lb. shear -- definite resistance to biting, but can be handled with effort; 30 lb. shear strength or higher, blocks are too hard to bite off. Highly plastic materials did not give good shear strength values, since they tended to flow under the knife and did not show sharp end points. Very hard materials which cracked tended to give occasional low values, and these low values were discarded.

### 4. Impact Resistance

Impact resistance figures were also determined for the blocks. A satisfactory impact resistance test was developed using a slightly modified Gardner impact tester. The method and equipment are described in detail in Appendix A. The apparatus consisted of a weight which was dropped through a guide shaft onto the food blocks from increasing heights until it caused them to break. The impact

range reported for food blocks lay between the maximum drop height for the weight which would not result in breakage and the minimum drop height for the weight which would cause breakage. As with the shear strength test, a series of food blocks of various degrees of hardness was tested in developing a significance for the figures on impact resistance. The results of these trial tests with the impact tester are shown in Table XXVIII.

The data indicated that the following values should be specified as suitable impact breaking ranges for future food blocks: 2 - 10 in-lb, for hard nonplastic blocks; and 10 - 20 in-lb for plastic, flexible blocks. Blocks falling within the above ranges would appear sufficiently strong to meet the other physical requirements, and at the same time would have a satisfactory biting and chewing character.

5. Equilibrium Relative Humidity

Two preparations of the egg albumen binder used for preparing prototype blocks were tested for equilibrium relative humidity. The mixing and drying procedures for preparing the binders duplicated those for binders in the actual prototype blocks. Pastes containing 20 g. of water (Sample A) and 25 g. of water (Sample B) for each 20 g. of dry albumen were made up and dried in thin sheets at 100°F. The dried preparations were tested for equilibrium relative humidity at 78°F, using a slight modification of the procedure of Funk.1/ Procedures for preparing and testing the dried binders are described in detail in Appendix A.

The absorption isotherms obtained on Samples A and B are shown in Figs. A-2 and A-3 in Appendix A. The moisture content of Sample A at the start of the test was 3.9 per-cent. This value reached an equilibrium level of 4.3 per-cent in an atmosphere containing 11.1 per-cent relative humidity, and increased to an equilibrium value of 6.7 per-cent at 22.6 per-cent relative humidity. Progressive increases in the moisture content of the sample occurred at the three

1/ Funk, Willmer A., Modern Packaging, 20, 135 (1947).

higher relative humidity levels tested. The initial moisture value for Sample B was 4.8 per-cent, and this value increased to equilibrium figures of 4.3 per-cent and 6.6 per cent, respectively, at 11.1 per-cent and 22.6 per-cent relative humidity. Progressive increases in moisture content were again shown at the three higher moisture levels tested.

The results indicated that the dried binders maintain approximately their initial moisture content when exposed at room temperature to atmospheres containing up to about 12 per-cent relative humidity. The initial moisture content of the binders produced satisfactory stability in prototype blocks under accelerated storage (see Section D above). Therefore, the dried binders are considered stable when they are protected against atmospheres containing not more than 12 per cent relative humidity at room temperature. For all practical purposes, the equilibrium relative humidity values for Samples A and B are identical. This is shown in Figs. A-2 and A-3.

## III. DISCUSSION

Two types of adhesives, wet and hot melt, proved to be the best binders for forming blocks containing combinations of food components normally difficult to bind. Conventional tableting procedures are frequently limited by the particle size and flow characteristics of the components being tableted. Both the wet and the hot melt adhesives tend to minimize these difficulties. Either method is applicable for finding components having a wide range of physical and chemical characteristics.

Our basic test formula consisted of 50 per-cent prefried bacon, 30 per-cent precooked rice, and 20 per-cent dry nonfat milk solids. The oily flexible meat particles were the most difficult to bind. However, we were able to form structurally strong blocks containing 50 per-cent prefried bacon. We believe that the size and physical characteristics of these blocks established that almost any meat particle of any size suitable for use in rations could be made into blocks.

Flexible food components require a supporting structure to minimize deformation under stress in the finished blocks. Rice was a supporting structure in the test blocks. Without it or an

equivalent supporting structure, satisfactory production of test formula blocks probably would be more difficult.

Dry nonfat milk was the third component in the experimental formula. We, therefore, started out by using milk as an adhesive, and were able to show that most of the physical requirements for the blocks could be met in this way with the bacon, rice and milk alone. However, the milk had a shorter shelf life than we considered desirable. Other adhesives were evaluated in an attempt to make up the deficiencies in milk. Some of the other adhesives had further advantages. One of the greatest of these was that they would withstand prolonged storage at high temperature. All of the ones used extensively were good dietary components, and the levels did not exceed those which might be recommended for a well-balanced diet. Dried egg albumen was selected as the adhesive to prepare the food blocks sent to the sponsor.

We felt that we could produce prototype blocks to the desired specifications, if we could first produce basic test formula blocks which met the specifications. Therefore, our work was first concentrated on test blocks. Test blocks were palatable and chewable, and met storage stability requirements when milk binder was replaced with egg. They also resisted deformation, except in the upper moisture range, but we showed that a sodium caseinate-lactose binder was helpful for added strength at this point. Some of the gelatin hot melts, if slightly dry, probably would provide enough strength to prevent deformation at the highest moisture level.

Very dry blocks shattered on a 10-ft. drop, but future work with small amounts of plasticizing lecithin, starch, sorbitol or glycerin may help prevent this difficulty. The fracture of blocks containing 20 - 25 per-cent moisture at -65°F is essentially that of ice, and it was, therefore, very hard to prevent. One approach might be to make sure that most of the moisture, particularly that in the adhesive, was very finely emulsified.

Although the mixtures were sticky, it appeared that blocks containing wet adhesive could be formed as rapidly as desired. This might be done commercially with an extruder, or with a machine which rolled the mix into a series of molds conveyed on a belt. Thus, the cost and capacity limitations of a high pressure tableting machine would be avoided.

In our work, blocks made with wet adhesive had to be dried from 12 - 16 hr. Although this time might be cut down in efficient commercial practice, it would be far more appealing to do so by using hot melt adhesives. As described in this report, the blocks made with these would require very little drying, or none at all, if the small amount of water in the binder could be tolerated in the formula.

It is probable that most blocks made with wet or hot melt adhesives will harden on prolonged storage. If this proves true, many ingredients are available which could be selected and evaluated as softening agents.

Yellowing can also possibly be expected as another difficulty in storage. We believe, however, that it is a typical nonenzymatic browning and can thus be decreased by preventing contact of amino acids with aldehyde sugars. Sorbitol would, therefore, seem like a better choice than glucose for hot melts made with gelatin.

The wet binder process appears adaptable for commercial production, since it involves only conventional operations of mixing, forming, and drying. Even under the best conditions, however, drying will require several hours and will, therefore, represent the slowest step in the process. The hot melt procedure, which simply requires cooling of the finished blocks would, therefore, produce a considerable increase in the production rate.

In production with the latter process, melted adhesive could be metered in at a controlled temperature over the other ingredients on a continuous mixing conveyor. Mixing would then continue for only a very short further flight on the conveyor. The mixture would then go to a continuous block forming machine. The latter is pictured as consisting of a continuous belt made in the form of a grating. The openings in the grating would have the desired length and width of the blocks to be formed, and would be closed at the bottom. The mixture of adhesive with the food ingredients would be pushed into these openings, and carried along by the belt until cool. The blocks would then be pushed out and further chilled to harden.

# APPENDIX A

## SUPPLEMENTARY INFORMATION

A. Equipment and Testing Methods

1. One and one-quarter inch steel die: The die had been used for other projects and was not constructed specifically for this work. It had a square chamber measuring 1-1/4 in. x 1-1/4 in. x 2-1/2 in. deep. The chamber was fitted with a plunger and a detachable bottom plate, both of which were dished to a depth of 1/16 in. The die was either used for compression of blocks or simply as a forming mold.

2. One and one-half by three inch die: The die was patterned on the small die above. It had an inside width and length of 1-1/2 in. x 3 in. It was constructed of chrome plated steel and was built to withstand pressures up to 5,000 psi. The die chamber was 2-1/2 in. deep and had rounded corners. The die block was in the form of a cylinder 2-1/2 in. high. It measured 4-1/8 in. in diameter over the top 2 in., and 4-3/8 in. in diameter over the bottom 1/2 in. The extra diameter at the bottom strengthened it in order to withstand the applied pressure. The die plunger was 2-3/4 in. high and rounded at the corners in order to fit the chamber. The face of the plunger was dished to a depth of 1/16 in. to produce rounded edges on the blocks. The body of the die was mounted on a plate which was dished in the same manner as the plunger. Alignment of these two parts was obtained by means of pins in the base of the plate. A metal collar provided supports for the die when pushing out the plunger. The die was used either for compression of blocks or simply as a mold.

3. Viscosity: The viscosity of hot melt adhesive suspensions was determined by means of a Brookfield Model LVF Viscosimeter.

4. Moisture: Except in the case of the equilibrium relative humidity determinations, all moistures were determined by means of an IR Moisture Matic Balance, made by Moore-Milford Corporation, Skokie, Illinois. The samples to be analyzed were coarsely ground and laid out on the pan of the balance. The time and temperature of heating were then set to predetermined levels, which produced moisture values corresponding with those obtained by other methods. The samples were reweighed on the pan after drying, and the loss in weight was recorded as moisture.

5. Breaking strength: The breaking strength of individual food blocks gave a measure of their over-all resistance to disintegration. To obtain a numerical reference indicating the strength of each block prepared, a modified Warner-Bratzler meat tenderness tester, equipped with a registering Hanson Model 60 dairy scale was used. The shear knife with which this apparatus was originally equipped was replaced with a flat wooden block, which was drawn along the horizontal surface of the tester in the same way as the shear knife. The food blocks to be tested were placed against a stationary steel block in the tester, and the wooden block was drawn up against them mechanically. The maximum pressure attained before the test food block collapsed was registered on the scale. The food blocks were arranged so that the breaking pressure was applied laterally, in other words, parallel with the long axis. Breaking strength values of 10 lb., or greater, indicated solid well-formed blocks.

6. Ten-foot drop test: When this test was performed at room temperature, the food blocks were simply dropped from a height of 10 ft. on a cement floor. They were weighed before and after dropping and the per cent loss in weight was recorded as the 10-ft. drop loss. It represented the amount of material lost from the blocks due to fragmentation. When this value was over 40 per-cent, it was noted that the blocks had shattered.

When the 10-ft. drop loss test was performed at 100°F, the blocks were brought to temperature equilibrium in a 100° cabinet. They were then carried in a small insulated container, also at this temperature, to the top of the ladder from which they were dropped. They were dropped within 15 sec. after removing them from the oven, and immediately after withdrawing from the container, in order to avoid cooling.

For performing the 10-ft. drop test at -65°F, a 1,500 ml. beaker was filled with Dowanol PN, which was cooled to -65° by gradually adding pieces of dry ice. The blocks were directly immersed in the Dowanol and the temperature maintained for 15 min. by continued addition of dry ice, with stirring. They were dropped on the floor directly from the Dowanol bath.

7. Deformation: In the method developed for determining deformation, the changes in the dimensions of the blocks were measured by means of a vernier caliper. For running the tests, the blocks were

wrapped lightly in nonrigid aluminum foil to prevent moisture loss. Weights were used for continuously applying pressure on the flat side of the small food blocks. The weights were prevented from tipping over by means of a ring held in a ring stand. The food blocks were placed on the base of this stand and the entire arrangement set up in a constant temperature cabinet at 100°F. The weights used were steel blocks cut from 2 in. x 2 in. stock, and having a length of 6-15/16 in. They weighed approximately 7.8 lb. which applied a pressure of 5 psi on the small test blocks. Deformation was reported as the per cent decrease in the thickness of the blocks after application of the weight for 24 hr. at 100°, and as the increase in the length and width under the same compression.

8. Shear strength: Shear strength values were obtained using a modification of the Warner-Bratzler meat tenderness tester. The food blocks were placed on edge in the tester, with the back side against the mounting panel of the tester which is advanced mechanically at a steady rate. A specially constructed shear knife, with the blade held in a vertical position, was mounted firmly on a wooden frame. This frame was connected to the registering scale of the tester by means of rods and a yoke, in such a way that the food blocks were pressed directly against the shear knife as they were pushed forward by the advancing mounting panel. Thus, the scale registered the number of pounds of pressure required to push the knife through the food blocks from one of the large sides to the other; in other words, through a 1/2 in. thickness in a typical food block.

The shear knife was made from a 0.060 in. sheet of black iron, cut in the form of a 2 in. x 3 in. rectangle. One of the 2 in. sides served as a blade. The blade was made by milling a 45° bevel across the face of this side. The sharp tip of the bevel was rounded off on a grinding wheel over approximately 1/3 the thickness of the knife, back about 0.020 in. from the original edge of the knife in the direction of the opposite surface. The blade was mounted so that it cut a small food block all the way across its 1-1/4 sq. in. face.

To determine the shear strength of a block, the block was placed in the mounting panel of the machine. The motor was turned on and the block pressed against the shear knife until the knife cut it in half. The maximum pressure required for this cutting was recorded on the scale. A photograph showing the operation of the shear strength tester is presented in Fig. A-1.

Fig. A-1 Operation of Shear Strength Tester

9. Impact resistance: Impact resistance was determined by means of a slightly modified Gardner impact tester, which has been described in detail by its developers.[1] The tester was equipped with a cylindrical metal impact weight, which is dropped through a guide tube onto the sample to be tested. In applying the Gardner tester to food blocks, the blocks were arranged so that the large sides were at 90° to the path of the impact weight, and in such a position that the weight would hit in the center of the blocks. The food blocks were supported by a 1 in. block of hardwood, mounted solidly on the bottom frame of the tester. The face of the impact weight contained a 1/2 in. diameter steel ball, mounted in the center of the weight and imbedded up to 1/2 of its diameter. The remainder of the face of the impact weight was bevelled back from the ball at a 45° angle to the long axis of the weight.

Breakage for any food block under impact was defined as the condition under which pieces of the block cleanly separated, or under which a crack opened in the block in such a way that the two sides were completely separated.

The impact breaking range for any series of food blocks lay between the maximum impact which would not cause breakage and the minimum impact which would cause breakage. Ranges were reported in inch-pounds.

10. Equilibrium relative humidity: Equilibrium relative humidity was determined on two samples of egg albumen binder which were prepared in exactly the same manner as when they were used in the prototype blocks. Paste Sample A was made up with 100 g. of dry egg albumen and 100 g. of water; and Paste Sample B was made up with 100 g. of dry egg albumen and 125 g. of water. The initial lumps of dry albumen were broken by stirring vigorously for 15 min. in a beaker. The pastes were then covered and held in a refrigerator for 6 hr. During this period, they were mixed three times. The pastes were then spread on aluminum trays to a controlled depth, using a scraper with clearance bars which held it 1/16 in. above the trays. The samples on

1/ Gardner, Henry A., and Sward, C. G., "Physical and Chemical Examination of Paints, Varnishes, Lacquers, and Colors," Henry A. Gardner Laboratory, Inc., Bethesda, Maryland, 11th Edition, p. 188A (January, 1950).

the trays were dried 16 hr. in a circulating warm air oven at 100°F. The dry material was broken into a powder which passed a 6-mesh screen and was held in a tightly sealed jar until tested.

The samples of dried egg albumen binder were tested for equilibrium relative humidity by a procedure based on that of Funk.1/ One gallon pinch top cans served as relative humidity chambers. A 1,500 ml. beaker was placed in each can, and the beakers contained saturated salt solutions at a depth of about 1/2 in. in order to maintain constant relative humidity. The egg albumen samples were placed in 93 x 15 mm. Petri dishes. They were spread evenly across the bottom of the dishes at a uniform depth of about 1/16 in. The dishes were suspended in the beakers at a distance of 2 in. above the saturated salt solutions by means of wire stirrups. After the samples had been arranged in the dishes, the cans were sealed and the moisture content of the samples was allowed to come to equilibrium under the constant humidities maintained by the salt solutions at a temperature of 78°F.

The constant humidity test chambers were held in a constant temperature room at 78 ± 2°F. Six constant humidities were maintained for each sample by means of saturated salt solutions as follows: $LiCl_2$ - 11.1 per-cent R.H.; $KC_2H_3O_2$ - 22.6 per-cent R.H.; KCNS - 45.3 per-cent R.H.; NaBr - 57.8 per-cent R.H.; $NaC_2H_3O_2$ - 73.6 per-cent R.H.; and $NH_4H_2PO_4$ - 92.2 per-cent R.H. At the end of each day of storage, the dish from each chamber was briefly removed, covered and weighed in order to determine the weight of the contents. The daily weighings were continued until each sample reached a constant weight. The moisture content of each sample was then determined by the A.O.A.C. vacuum oven method. Samples of the dried binders which had not been exposed to humidity after drying were similarly analyzed. Absorption isotherms for Samples A and B were prepared by plotting the moisture content of each stored sample against the relative humidity at which it had been stored (see Figs. A-2 and A-3).

---

1/ Funk, Willmer A., Modern Packaging, 20, 135 (1947).

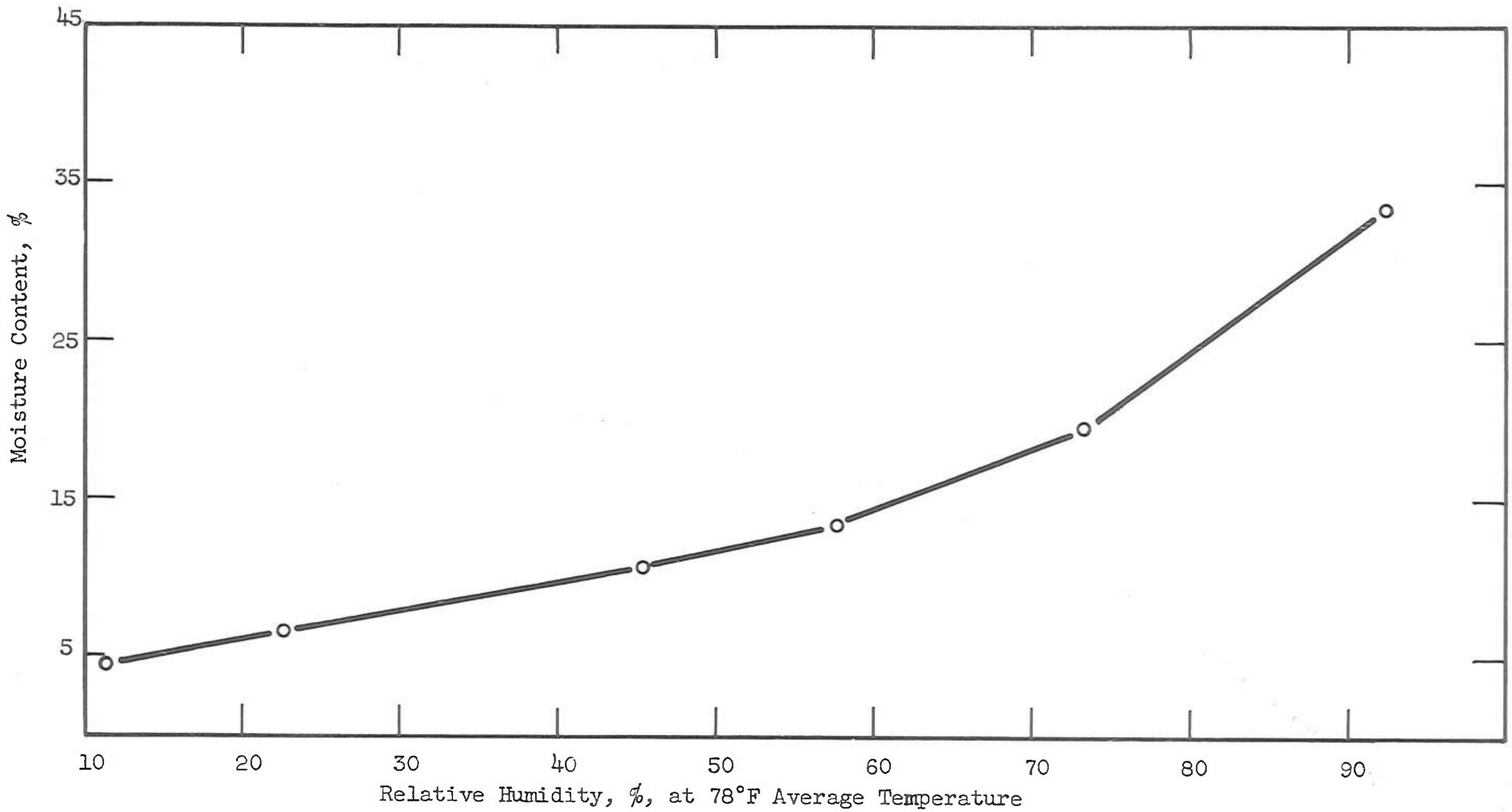


Fig. A-2 - Absorption Isotherm for Sample A

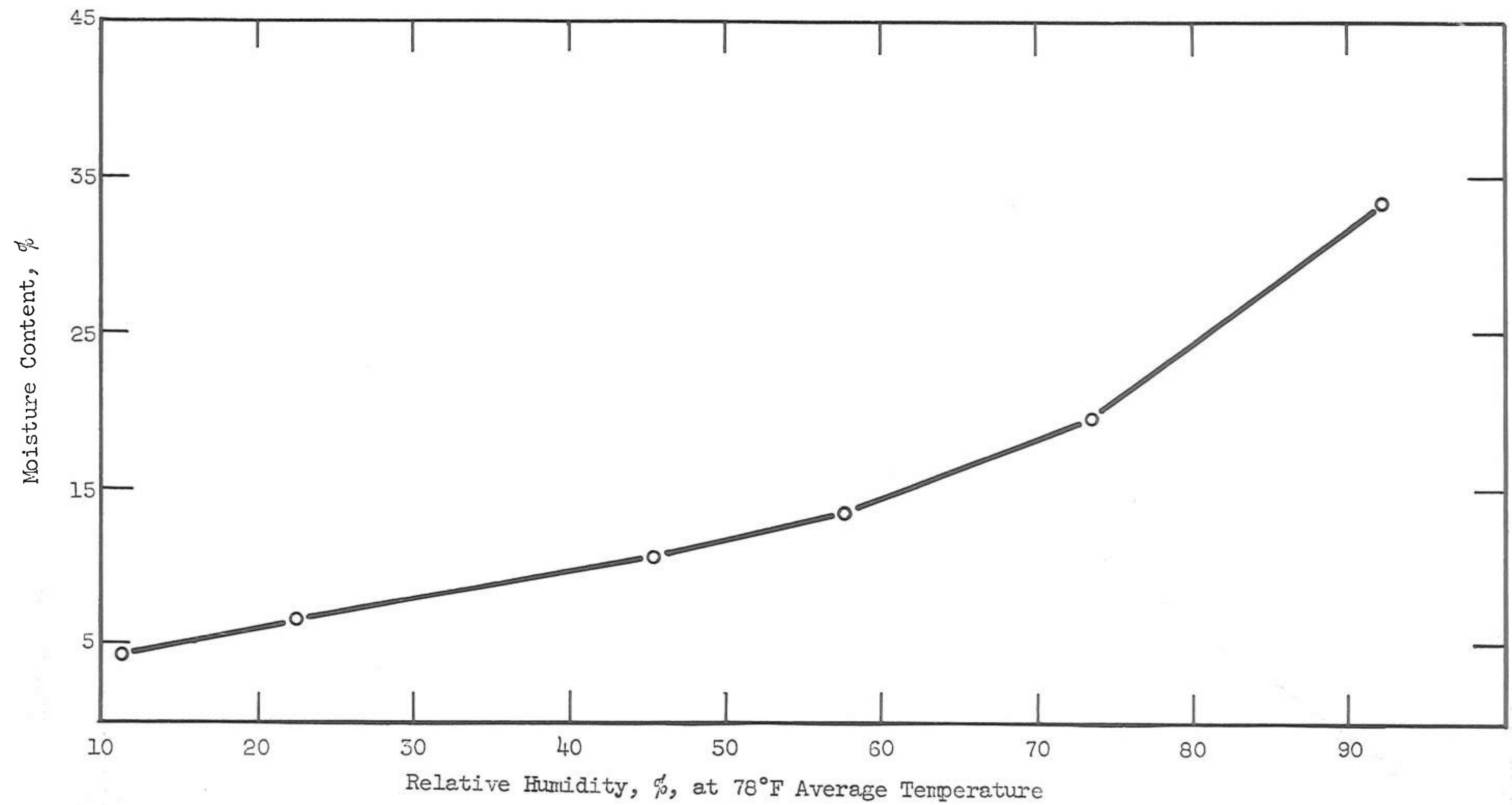


Fig. A-3 - Absorption Isotherm for Sample B

B. Ingredients

| | |
|---|---|
| Bacon (Prefried) | Oscar-Mayer, Madison, Wisconsin. |
| Beef (Dried) | Quartermaster Corps (Beef, ground, precooked, dehydrated -- Limited Production Purchase Description LP/P. DES C-182-62, 20 June 1962). |
| Beeswax | White, U.S.P., Matheson, Coleman & Bell, Cincinnati, Ohio. |
| Cerelose | Glucose, Corn Products Sales Company, New York. |
| Chicken (Dried) | Quartermaster Corps (Chicken pieces, precooked freeze-dehydrated, Interim Purchase Description, IP-DES CS-5-1, 15 May 1961). |
| Coconut (Shredded) | "Baker's", General Foods Corp., White Plains, New York. |
| Coconut Butter (Hydrogenerated to 98° melting point) | S. W. Noggle Company, Kansas City, Missouri. |
| Cornstarch, Pregelatinized | No. 78-1215, National Starch Products, Inc., New York. |
| Cornstarch, Ungelatinized | "Argo", Corn Products Sales Company, New York. |
| Cracker, (All Purpose Survival Ration) | Limited Coordination Military Specification, MIL-C-43057 (QMC) 17 January 1962. |
| Egg Albumen | S. W. Noggle Company, Kansas City, Missouri. |
| Frodex 24 | American Maize Products, New York. |
| Gelatin (Centura) | Swift and Company, Chicago, Illinois. |
| Gelatin (Pharmaceutical grade) | Swift and Company, Chicago, Illinois. |
| Gloro 20 (Completely hydrogenated coconut oil) | Proctor and Gamble Company, Cincinnati, Ohio |
| Gum Tragacanth | Stein, Hall and Co., Inc.,New York. |
| Lactose | Sheffield Chemical, Norwich, New York. |
| Lecithin | "Sta-Sol UF", A.E. Staley Manufacturing Company, Decatur, Illinois |

| | |
|---|---|
| Milk (Nonfat dry) | Carnation Instant Nonfat Dry Milk Carnation Company, Los Angeles, California. |
| Myrj 52 | Atlas Powder Company, Wilmington, Delaware. |
| Peanuts (Defatted) (10 lb. Expeller Meal) | Planter's Peanut Div., Standard Brands, Inc., Suffolk, Virginia. |
| Peanuts (Dry Roasted) | Planter's Peanut Div., Standard Brands, Inc., Suffolk, Virginia. |
| Rice (Precooked) | Minute Rice, General Foods Corporation, Battle Creek, Michigan. |
| "Sheftene" Sodium Caseinate | Sheffield Chemical, Norwich, New York. |
| Sorbitol (Crystalline) | Atlas Chemical Industries, Inc., Wilmington, Delaware. |
| Sorbo | Atlas Chemical Industries, Inc., Wilmington, Delaware. |
| Soybean Expeller Cake | A. E. Staley Manufacturing Company, Decatur, Illinois. |
| Soy Grits | A. E. Staley Manufacturing Company, Decatur, Illinois. |
| Wheat Flour | Queen of the Pantry, Waggoner-Gates Milling Company, Independence, Missouri. |
| Wheat Gluten | Hercules Powder Company, Wilmington, Delaware. |

APPENDIX B

TABLES I THROUGH XXVIII

TABLE I

BREAKING STRENGTH AND FAT LOSS IN SMALL BASIC TEST FORMULA BLOCKS COMPRESSED WITHOUT BINDER

| Pressure (lb.) | Dwell Time (sec.) | Fat Loss[a] (%) | Breaking Strength (lb.) |
|---|---|---|---|
| 500 | 3 | 3.0 | 1.0 |
| 500 | 15 | 3.7 | 1.6 |
| 750 | 3 | 4.0 | 0.6 |
| 750 | 15 | 5.4 | 1.7 |
| 1,000 | 3 | 2.8 | 1.3 |
| 2,000 | 3 | 5.6 | 2.1 |
| 2,000 | 15 | 7.3 | 2.1 |
| 3,000 | 3 | 6.4 | 1.8 |
| 4,000 | 3 | 6.7 | 1.8 |

a/ The loss in weight of the blocks on compression was assumed to be entirely in the form of pressed-out fat.

TABLE II

EFFECT OF VARIOUS PRETREATMENTS OF THE RICE IN SMALL BASIC TEST FORMULA BLOCKS MADE WITH GROUND BACON, GROUND RICE[a] AND 1:1 MILK BINDER[b]

| Pretreatment of Rice | Temp. °F of Mix when Binder Added | Moisture (%) | Breaking Strength Range for Blocks (lb.) | Block Loss on 10-ft. Drop Test |
|---|---|---|---|---|
| No pretreatment | 70 | 9.5 | 4-6 | 3 out of 5 blocks shattered |
| Adjusted to 30% moisture | 70 | 9.5 | 7-9 | No data |
| Held 2 hr. with bacon at room temperature | 70 | 9.5 | 7-12 | 0 out of 5 blocks shattered |
| Held 2 hr. with bacon at 140°F | 140 | 9.5 | 3-4.5 | 2 out of 5 blocks shattered |
| Held 2 hr. with bacon at 140°F | 70 | 9.5 | 5-9.6 | 3 out of 5 blocks shattered |
| Rice and bacon mixed 5 min. by hand | 70 | 9.5 | 9-11 | 0 out of 5 blocks shattered |

a/ 16-20 mesh.
b/ One part dry nonfat milk solids to one part water by weight.

TABLE III

EFFECT OF VARIOUS PRETREATMENTS OF THE RICE IN SMALL BASIC FORMULA BLOCKS MADE WITH 3/8-INCH BACON, WHOLE RICE, AND 1:1 MILK BINDER

| Pretreatment of Rice | Moisture in Blocks (%) | Average Breaking Strength of Blocks[a] (lb.) | Average 10-ft. Drop Loss of Blocks (%) |
|---|---|---|---|
| None | 9.5 | 19.9 | 1.2 |
| Held 2 hr. with bacon at room temperature | 9.5 | 20.3 | 1.2 |
| Held with bacon 1 hr. at 100°F, mixture cooled to room temperature before adding binder | 9.5 | 25.6 | 1.0 |
| Held with bacon 1 hr. at 150°F, mixture cooled to room temperature before adding binder | 9.5 | 25.7 | 0.6 |
| Held with bacon 2 hr. at 100°F, mixture cooled to room temperature before adding binder | 9.5 | 24.5 | 1.3 |
| Held with bacon 1 hr. at 100°F, binder added to warm mixture | 9.5 | 23.6 | 0.8 |

a/ Each average for breaking strength and drop loss was established with from 5 to 18 blocks.

TABLE IV

EFFECT OF AGING ON SMALL TEST BLOCKS[a]

| Binder Composition | Moisture in Blocks (%) | Days of Storage | Breaking Strength (lb.) | % Deformation in 24 hr. under 5 psi Pressure at 100°F: Vertical Shrinkage (%) | Lateral Expansion (%) |
|---|---|---|---|---|---|
| 1:1 Nonfat dry milk + | | | | | |
| Water | 21 | 0 | 5.4 | 38 | 10 |
| " | " | 3 | 7.8 | 11 | 4 |
| " | " | 5 | 12.3 | 18 | 19 |
| " | " | 7 | 13.1 | 15 | 3 |
| " | " | 10 | 14.3 | 16 | 4 |
| " | " | 14 | 12.5 | 9 | 6 |
| 2:7 Sodium caseinate + | | | | | |
| Water | 24.5 | 0 | 12.3 | 35 | 7 |
| " | " | 3 | Crushed | 28 | 11 |
| " | " | 5 | " | 32 | 10 |
| " | " | 7 | " | 38 | 19 |
| " | " | 10 | " | 37 | 15 |
| " | " | 14 | " | 29 | 9 |

a/ 50% bacon, 30% rice and 20% dry nonfat milk solids or sodium caseinate.

TABLE V

BREAKING STRENGTH OF SMALL TEST BLOCKS PREPARED
WITH A 20% STARCH BINDER AND VARIOUS LEVELS OF MOISTURE

| Series | Grams Water/20 g of Binder Ingredients | Moisture in Dried Block (%) | Average Breaking Strength of Blocks (lb.) |
|---|---|---|---|
| A | 20 | 22.6 | 3.0 |
| | 20 | 19.8 | 5.7 |
| | 20 | 13.6 | 13.7 |
| B | 30 | 28.3 | 2.5 |
| | 30 | 25.8 | 3.7 |
| | 30 | 20.0 | 10.8 |
| C | 40 | 29.5 | 3.7 |
| | 40 | 22.8 | 9.2 |
| | 40 | 20.1 | 14.1 |
| D | 50 | 29.5 | 2.5 |
| | 50 | 25.4 | 10.6 |
| | 50 | 23.8 | 11.2 |

TABLE VI

EFFECT OF THE LEVEL OF WATER USED IN A BINDER CONSISTING OF 90% NONFAT DRY MILK AND 10% INSTANT CORNSTARCH

| Grams of Water Used for 20 g. of Binder Mixture | Moisture in Dried Block (%) | 10-ft. Drop Loss (%) | Breaking Strength (lb.) |
|---|---|---|---|
| 20 | 17.7 | 1.5 | 9.6 |
| 30 | 19.9 | 0.3 | 12.1 |
| 40 | 21.5 | 0.8 | 12.8 |

TABLE VII

EFFECT OF FINAL MOISTURE CONTENT ON THE BREAKING STRENGTH OF SMALL TEST BLOCKS MADE WITH 10% INSTANT STARCH BINDER

| Moisture in Dried Block (%) | Breaking Strength (lb.) |
|---|---|
| 27.4 | 5.1 |
| 25.6 | 7.2 |
| 24.0 | 11.8 |
| 22.2 | 10.8 |
| 19.7 | 14.8 |
| 16.3 | 15.2 |
| 17.0 | 15.0 |

TABLE VIII

EFFECT OF ADDITIVES TO THE MILK-WATER BINDER FOR SMALL TEST BLOCKS

| Composition of Binder Dry Milk (g.) | Cerelose (g.) | Water (g.) | Moisture in Block (%) | Average Breaking Strength of Blocks (lb.) | Average 10-ft. Drop Loss of Blocks (%) |
|---|---|---|---|---|---|
| 20 | 5 | 20 | 9.5 | 23.7 | 0.6 |
| 20 | 5 | 25 | 9.5 | 26.1 | 0.7 |
| 20 | 10 | 25 | 9.5 | 18.2 | 0.6 |
| 20 | 5 | 17 | 9.5 | 21.5 | 0.5 |
| 20 | - | 20 | 9.5 | 22.5 | 0.7 |
| 20 | 5 g. glycerol | 20 | 9.5 | a/ | 1.3 |

a/ Blocks bent rather than broke.

TABLE IX

EFFECT OF REPLACING MILK WITH CERELOSE IN THE 1:1 MILK BINDER FOR SMALL TEST BLOCKS

| Portion of the Milk Replaced with Cerelose (%) | Moisture in Blocks (%) | Average Breaking Strength of Blocks (lb.) | Average 10-ft. Drop Loss of Blocks (%) |
|---|---|---|---|
| 0 | 9.5 | 25.2 | 0.7 |
| 25 | 9.5 | 22.7 | 0.9 |
| 50 | 9.5 | 14.5 | 2.1 |
| 75 | 9.5 | 7.1 | 1.5 |
| 100 | 9.5 | a/ | 20.0 |

a/ Too low to read.

TABLE X

EFFECT OF CORNSTARCH IN THE BINDER OF SMALL TEST FORMULA BLOCKS (COOKED AFTER MOLDING)

| Series | Level for Raw Starch in Binder (%) | Moisture Content of Blocks (%) | 10-ft. Drop Loss (Room Temperature) (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F: Vertical Shrinkage (%) | Lateral Expansion (%) | Breaking Strength (lb.) |
|---|---|---|---|---|---|---|
| Wet | 10 | 16 | < 1 | > 10 | < 10 | 10.9 |
| Wet | 20 | 16 | < 1 | 10 | < 10 | 14.8 |
| Wet | 40 | 14 | < 1 | > 10 | < 10 | Not run |
| Wet | 80 | 15.5 | 9 | > 10 | < 10 | Not run |
| | Control 10% instant starch 90% NFD milk | 22.5 | < 1 | > 10 | < 10 | 7.7 |
| Dry | 20 | 11.5 | < 1 | < 10 | < 10 | 16.5 |
| Dry | 80 | 8 | 12.5 | 10 | Not run | 8.3 |
| | Control 10% instant starch 90% NFD milk | 10 | 1.3 | 10 | 10 | 18.0 |

TABLE XI

EFFECT OF WHEAT FLOUR IN THE BINDER OF SMALL TEST FORMULA BLOCKS (COOKED AFTER MOLDING)

| Series | Level for Flour in Binder (%) | Moisture Content of Blocks (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F | | Breaking Strength (lb.) |
|---|---|---|---|---|---|
| | | | Vertical Shrinkage (%) | Lateral Expansion (%) | |
| Wet | 40 | 19.9 | 15 | < 10 | 5.8 |
| Wet | 80 | 21.2 | 31 | > 10 | 2.1 |
| | Control 10% instant starch | 20.0 | > 10 | > 10 | 7.7 |
| Dry | 10 | 14.6 | 14 | < 10 | 11.0 |
| Dry | 20 | 14.6 | 18 | < 10 | 10.6 |
| Dry | 40 | 15.1 | 15 | < 10 | 7.1 |
| Dry | 80 | 15.5 | 29 | > 10 | 4.0 |
| | Control 10% instant starch | 15.0 | > 10 | < 10 | 13.2 |

TABLE XII

EFFECT OF WATER LEVEL USED IN MAKING UP A SMALL TEST BLOCK BINDER CONSISTING ENTIRELY OF WHEAT FLOUR (COOKED AFTER FORMING)

| Grams of Water for 20 g. of Flour | Moisture Content of Blocks (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F | | Breaking Strength (lb.) |
|---|---|---|---|---|
| | | Vertical Shrinkage (%) | Lateral Expansion (%) | |
| 30 | 11.6 | 21 | 11 | 3.0 |
| 25 | 12.2 | 13 | 5 | 4.2 |
| 20 | 14.0 | 15 | 3 | 4.9 |
| 15 | 12.4 | 13 | 3 | 4.6 |
| 10 | 13.4 | 19 | 8 | 4.3 |

TABLE XIII

DEFORMATION AND BREAKING STRENGTH OF SMALL TEST FORMULA BLOCKS MADE WITH SODIUM CASEINATE BINDER

| Grams of Water for 20 g. of Sodium Caseinate | Moisture Content of Blocks (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F | | Breaking Strength (lb.) |
|---|---|---|---|---|
| | | Vertical Shrinkage (%) | Lateral Expansion (%) | |
| 40 | 18.7 | 24 | 10 | 17.6 |
| 50 | 20.3 | 35 | 7 | 20.0 |
| 60 | 21 | 25 | 5 | 20.4 |
| Control: 20 g. dry milk plus 20 g. water | 14.3 | 12 | 1 | 14.7 |
| 16 g. sodium caseinate, 4 g. lactose, 20 g. water | 19 | 16 | 4 | 19.0 |

TABLE XIV

DEFORMATION AND BREAKING STRENGTH OF SMALL TEST FORMULA BLOCKS MADE WITH SODIUM CASEINATE BINDER (SECOND SERIES)

| Grams of Water for 20 g. of Sodium Caseinate | Moisture Content of Blocks (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F | | Breaking Strength (lb.) |
|---|---|---|---|---|
| | | Vertical Shrinkage (%) | Lateral Expansion (%) | |
| 55 | 12.3 | 3 | 0 | > 30 |
| 70 | 11.4 | 0 | 0 | > 30 |
| 85 | - | 0 | 0 | > 30 |
| Control: 20 g. dry milk plus 20 g. water | 12.8 | 6 | 0 | 25.7 |

TABLE XV

DEFORMATION AND BREAKING STRENGTH OF SMALL TEST FORMULA BLOCKS MADE WITH EGG ALBUMEN BINDER

| Series | Series of Grams of Water for 20 g. of Egg Albumen | Moisture Content of Blocks (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F: Vertical Shrinkage (%) | Lateral Expansion (%) | Breaking Strength (lb.) |
|---|---|---|---|---|---|
| Uncooked | 15 | 12.0 | 6 | 0 | 10.9 |
| Uncooked | 20 | 12.8 | 9 | 3 | 16.0 |
| | Control: 20 g. dry milk plus 20 g. water | 13.4 | 21 | 3 | 17.7 |
| Cooked | 20 | 12.4 | 6 | 0 | 19.5 |
| Cooked | 25 | 11.4 | 11 | 3 | 19.8 |
| | Control: 20 g. dry milk plus 20 g. water | 14.0 | 12 | 3 | 19.2 |

TABLE XVI

RESULTS OBTAINED IN STRAIGHT PRESSURE TABLETING EXPERIMENTS ON MODIFIED[a] BASIC FORMULA SMALL BLOCKS MADE WITH DUSTED BACON

| Series | Formula[a] | | Bacon Particle Size (in.) | Total Jack Pressure (lb.) | Physical Data | | | Delamination in Block[b] |
|---|---|---|---|---|---|---|---|---|
| | Dusting Material (15%) | Ground Binder (20%) | | | Breaking Strength (lb.) | Drop Loss 5-ft. (%) | Drop Loss 10-ft. (%) | |
| 1 | Control ground rice[c] not dusted on bacon | Dry milk | 1/4 | 2,000 | 3.5 | 2 | 27 | ++ |
| | Control ground rice[c] not dusted on bacon | Dry milk | 3/8 | 2,000 | 0 | 100 | 100 | ++ |
| 2 | Ground rice | Soybean meal | 1/4 | 2,000 | 0 | 4 | 4 | ± |
| | Ground rice | Soybean meal | 3/8 | 2,000 | 0.8 | 41 | 48 | ± |
| | Ground rice | Soybean meal | 3/8 | 2,000 | - | 46 | - | ± |

TABLE XVI (Continued)

| Series | Formula[a/] Dusting Material (15%) | Formula[a/] Ground Binder (20%) | Bacon Particle Size (in.) | Total Jack Pressure (lb.) | Physical Data: Breaking Strength (lb.) | Physical Data: Drop Loss 5-ft. (%) | Physical Data: Drop Loss 10-ft. (%) | Delamination in Block[b/] |
|---|---|---|---|---|---|---|---|---|
| 3 | Precooked starch | Dry milk | 1/4 | 2,000 | 5.0 | 49 | 66 | ++ |
| | Precooked starch | Dry milk | 3/8 | 2,000 | 3.0 | 100 | 100 | ++ |
| 4 | Cerelose | Dry milk | 3/8 | 2,000 | 0 | 5 | 18 | ± |
| | Cerelose | Egg albumen | 3/8 | 2,000 | 1.5 | 32 | 66 | ++ |
| | Cerelose | Nonvital wheat gluten | 1/4 | 3,000 | 2.5 | 2 | 2 | ± |
| | Cerelose | Nonvital wheat gluten | 3/8 | 3,000 | 0.9 | 15 | 23 | ± |

TABLE XVI (Continued)

| Series | Formula[a/] Dusting Material (15%) | Formula[a/] Ground Binder (20%) | Bacon Particle Size (in.) | Total Jack Pressure (lb.) | Physical Data: Breaking Strength (lb.) | Physical Data: Drop Loss 5-ft. (%) | Physical Data: Drop Loss 10-ft. (%) | Delamination in Block[b/] |
|---|---|---|---|---|---|---|---|---|
| 5 | Wheat gluten | Cerelose | 1/4 | 5,000 | 0.2 | 1 | 10 | ++ |
| | Wheat gluten | Sorbitol | 1/4 | 2,000 | 3.6 | 1 | 3 | ++ |
| | Wheat gluten | Sorbitol | 3/8 | 2,000 | 2.4 | 5 | 9 | ++ |
| | Wheat gluten | Frodex | 1/4 | 2,000 | 3.4 | 2 | 9 | ++ |
| | Wheat gluten | Frodex | 3/8 | 2,000 | 2.5 | 2 | 4 | ± |
| | Wheat gluten | Ground rice | 1/4 | 2,000 | 0 | 52 | 62 | ++ |
| | Wheat gluten | Ground rice | 3/8 | 2,000 | 0 | 100 | 100 | ++ |
| | Dry milk | Cerelose | 1/4 | 2,000 | 0 | 1 | 23 | ± |
| | Dry milk | Cerelose | 3/8 | 5,000 | 0 | 7 | 100 | ++ |
| | Dry milk | Sorbitol | 1/4 | 5,000 | 1.2 | 1 | 1 | ± |

TABLE XVI (Concluded)

| Series | Formula[a/] Dusting Material (15%) | Formula[a/] Ground Binder (20%) | Bacon Particle Size (in.) | Total Jack Pressure (lb.) | Physical Data: Breaking Strength (lb.) | Physical Data: Drop Loss 5-ft. (%) | Physical Data: Drop Loss 10-ft. (%) | Delamination in Block[b/] |
|---|---|---|---|---|---|---|---|---|
| 5 (Concluded) | Dry milk | Sorbitol | 3/8 | 2,000 | 0.3 | 1 | 22 | ++ |
| | Dry milk | Frodex | 1/4 | 2,000 | 5.6 | 1 | 1 | ± |
| | Dry milk | Frodex | 3/8 | 2,000 | 3.1 | 1 | 1 | ++ |
| | 50% dry milk 50% ground rice | Cerelose | 1/4 | 5,000 | 0.5 | 1 | 1 | ± |
| | 50% dry milk, 50% ground rice | Cerelose | 3/8 | 2,000 | 0.2 | 17 | 32 | ++ |
| | 50% dry milk, 50% ground rice | Frodex | 1/4 | 2,000 | 7.4 | 1 | 1 | ± |

a/ Composition by weight equivalent to the basic test formula. All formulation contained 50% of bacon pieces.

b/ Severe delamination is designated by + , and slight delamination by ± .

c/ Ground minute rice, 100% through 28 mesh screen.

TABLE XVII

BREAKING STRENGTH OF SMALL SIZE BLOCKS MADE WITH BACON COATED WITH SORBO

| Series | Bacon Size | Bacon Coating | Batch Treatment | Tableting Pressure (lb.) | Block Breaking Strength (lb.) |
|---|---|---|---|---|---|
| 1 Prefried bacon | 3/8 | Sorbo-dried | Compressed dry | 1,000 | 2.2 |
| | | | | 2,000 | 2.3 |
| | | | | 5,000 | 9.2 |
| | 3/8 | Sorbo-dried | 0.5% moisture added to mix before compression | 2,000 | 3.4 |
| | | | | 4,000 | 11.2 |
| | 1/4 | Sorbo-dried | Compressed dry | 2,000 | 4.2 |
| | 1/4 | Sorbo-dried | 0.5% moisture added to mix before compression | 5,000 | 3.6 |
| 2 Partially defatted bacon | 3/8 | Sorbo-dried on partially defatted bacon | 23% moisture added to rice. Mix. Dried 15 min. 100°F. Compressed. Wet. | 2,000 | 15.8 |

TABLE XVII (Concluded)

| Series | Bacon | | Batch Treatment | Tableting Pressure (lb.) | Block Breaking Strength (lb.) |
|---|---|---|---|---|---|
| | Size | Coating | | | |
| 2 (concluded) | 3/8 | Sorbo-dried on partially defatted bacon | 23% moisture added to rice. Mix. Dried 15 min. 100°F. Compressed. | | |
| | | | Warm - 100°F | 2,000 | 13.4 |
| | | | Room temp. - 70°F | 2,000 | 9.2 |
| 3 | 3/8 | Sorbo and milk | 16% moisture added to rice. Mix. Temper. 15 min. Dry 1/2 hr. 120°F. Compressed. | | |
| | | | Warm - 120°F | 2,000 | 30.6 |
| | | | Warm - 120°F | 4,000 | 40.0 |
| | | | Cold - 35°F | 5,000 | 9.0 |

TABLE XVIII

SUBJECTIVE OBSERVATIONS OF CENTURA GELATIN - CERELOSE, HOT MELT ADHESIVES

| Formula No. | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| Composition | | | | |
| Centura, g. | 8 | 8 | 8 | 8 |
| Cerelose, g. | 4 | 8 | 12 | 16 |
| Water, g. | 10 | 10 | 10 | 10 |
| Grams of added water in 100 g. of adhesive mixture | 45.4 | 38.5 | 33.3 | 29.4 |
| Dispersion, warmed to 120-140°F viscosity | Medium thick, good for an adhesive | Slightly thinner than C-1 | Slightly thinner than C-2 | About same as C-3 |
| Adherence to fingers | Very firm adhesive bond | Firm, but slightly less so than C-1 | Slightly less tack than C-2 | Not too firm when warm, stuck tightly as it cooled |
| Adherence to waxed paper | Firm | Firm | Firm | Firm |

TABLE XVIII (Concluded)

| Formula No. | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| Adherence to waxed paper coated with bacon fat | Appreciable | Appreciable | Appreciable | Appreciable |
| Solid block, after standing 24 hr. at room temperature | | | | |
| Adherence to glass container | Firm, but not tena-cious | Same as C-1 | Hard to remove from glass | Hard to remove from glass |
| Solidity of block | Very firm, almost leathery | Same as C-1 | Same as C-1 | Possibly less firm than others |
| Stickiness of block | Not sticky | Same as C-1 | Very slightly sticky if held against fingers | Same as C-3 |

## TABLE XIX

### NOTES ON BASIC FORMULA BLOCKS MADE WITH CENTURA GELATIN - CERELOSE HOT MELT ADHESIVE BINDERS AND HELD AT ROOM TEMPERATURE FOR 24 HOURS

| Adhesive[a]: | No. 1 C-1 | No. 2 C-2 | No. 3 C-2 | No. 4 C-3 |
|---|---|---|---|---|
| Procedure | Pour melted adhesive on cool ingredient | Bacon and rice added to beaker of melted adhesive | Bacon added to warm mixture of melted adhesive and ground rice | Melted adhesive poured over bacon and rice preformed into block |
| Appearance of blocks | Well formed, quite firm, only slightly oily, consolidation needs improvement | Same as No. 1, but more oily and still less well consolidated | Well consolidated but very oily | Essentially no voids. Continuous matrix of adhesive surrounding bacon and rice particles |
| Reaction of rubbery blocks to breaking strength test | | | | |
| Maximum pressure recorded, lb. | 20 | 24 | 18 | 12 |

TABLE XIX (Concluded)

| Adhesive[a]: | No. 1 C-1 | No. 1 C-2 | No. 3 C-2 | No. 4 C-3 |
|---|---|---|---|---|
| Reaction | Block bounced out of press and recovered form completely | Rolled and slipped from press. Did not break | Turned over. Did not break | Turned over. Recovered original form completely |
| 10-ft. drop loss - % | 0 | 0 | 0 | 0 |

a/ See Table XVIII for adhesive composition.

TABLE XX

EFFECT OF RICE PARTICLE SIZE ON THE VISCOSITY AND AMOUNT OF "POUR ON" ADHESIVE REQUIRED FOR BASIC FORMULA BLOCKS

| Block Type | A | B | C |
|---|---|---|---|
| Rice particle size | Whole | 10-14 mesh | 16-20 mesh |
| Volume of 5 g. bacon (3/8") plus 3 g. rice tamped in 50 ml. beaker, ml. | 14.5 | 12.5 | 11.5 |
| Approximate maximum viscosity of a gelatin - cerelose hot melt which will completely penetrate tamped bacon-rice, cps. | 700 | 300 | 60 |
| Approximate amount of adhesive required to completely fill spaces in tamped bacon-rice, g. | 10 | 8 | 6 |
| Calculated percentage of voids in blocks (assuming adhesive runs 1 cc/g). | 69 | 64 | 52 |
| Amount of adhesive in bacon-rice-adhesive mixture, %. | 41 | 39 | 34 |

TABLE XXI

COMPOSITION AND CALCULATED ANALYSIS OF THE SIX PROTOTYPE BLOCKS SELECTED FOR STORAGE TESTING AND SHIPMENT TO THE SPONSOR

| Formula | B-1 Bacon | B-2 Chicken | B-3 Beef | C-3 Soy-Cracker | D-1 Peanut | D-2 Coconut |
|---|---|---|---|---|---|---|
| Composition, % | | | | | | |
| Prefried bacon | 45 | - | - | - | - | - |
| Precooked freeze-dried chicken | - | 50 | - | - | - | - |
| Dried beef | - | - | 50 | - | - | - |
| Soy grits | - | - | - | 30 | - | - |
| Cracker | - | 18 | 30 | 30 | - | - |
| Peanuts | - | - | - | - | 50 | - |
| Coconut | - | - | - | - | - | 50 |
| Precooked rice | 35 | - | - | - | 30 | 30 |
| Coconut fat | - | 12 | - | 20 | - | - |
| Egg albumen | 20 | 20 | 20 | 20 | 20 | 20 |
| Analysis | | | | | | |
| Moisture, % | 9.1 | 4.5 | 5.5 | 6.3 | 3.1 | 3.4 |
| Protein, % | 31.5 | 55.0 | 43.0 | 32.4 | 33.2 | 20.9 |
| Fat, % | 24.9 | 22.6 | 25.2 | 23.0 | 22.2 | 19.7 |
| Ash, % | 3.7 | 3.3 | 2.3 | 3.1 | 2.4 | 1.4 |
| Carbohydrate, % | 30.5 | 13.6 | 21.8 | 33.1 | 38.1 | 52.9 |
| Fiber, % | 0.1 | 0.4 | 0.4 | 1.1 | 1.3 | 2.1 |
| Calories/gram | 4.87 | 4.80 | 4.91 | 4.40 | 4.74 | 4.74 |
| Calories/ounce | 138 | 136 | 139 | 125 | 134 | 134 |

TABLE XXII

PROCEDURES FOR PREPARING THE PROTOTYPE BLOCKS SELECTED FOR STORAGE TESTING AND SHIPMENT TO THE SPONSOR

| Formula | B-1 Bacon | B-2 Chicken | B-3 Beef | C-3 Soy-Cracker | D-1 Peanut | D-2 Coconut |
|---|---|---|---|---|---|---|
| Procedure | | | | | | |
| Water for 20 g. albumen binder (g.) | 20 | 25 | 25 | 20 | 25 | 25 |
| Pressure for block forming | Hand | 1,000 lb. | 1,000 lb. | 1,000 lb. | Hand | Hand |
| Drying temperature (°F) | 120 | 120 | 120 | 120 | 100 | 100 |
| Drying time (hr.) | 16 | 16 | 16 | 16 | 16 | 16 |

TABLE XXIII

EFFECT OF THREE MONTHS' STORAGE AT 100°F ON THE ORGANOLEPTIC PROPERTIES OF PROTOTYPE BLOCKS

| Sample | Storage Temp. (°F) | Color | Odor | Rating[a] | Bite | Flavor | Rating |
|---|---|---|---|---|---|---|---|
| B-1 Bacon | 0 | Pink and white. | Mild, flat bacon, oily. | 6 | Crumbly | Oily, slightly tallowy. | 6 |
| | 100 | Definitely yellower than above. Rice is light yellow. | Slightly toasted bacon. Not rancid. | 6 | Crumbly | Slightly processed. Bacon toasted, not objectionable. | |
| B-2 Chicken | 0 | Light tan. | Flat, chicken slightly oily and slightly rancid. | 6 | Crumbly easy to bite. | Chicken, slightly fishy. | |
| | 100 | Same-slightly yellower. | Rancid odor. | 6 | Same as above. | Slightly more cracker flavor and less chicken flavor. | 6 |
| B-3 Beef | 0 | Flat brown, plus tan areas. | Beef, slightly tallowy. | 7 | Crumbly, easy to bite. | Quite good beef. | 8 |

TABLE XXIII (Continued)

| Sample | Storage Tamp. (°F) | Color | Odor | Rating[a] | Bite | Flavor | Rating |
|---|---|---|---|---|---|---|---|
| B-3 Beef (Concluded) | 100 | Same, but more yellow | Same, but more tallowy and slightly toasted. | 6 | Same | Off-flavor, oily | 6 |
| C-3 Cracker | 0 | Light creamy tan | Bland, cereal | 7 | Bit off cleanly, slightly hard. | Definitely bland, mild cereal. | 7 |
| | 100 | Light brown | Cereal, slightly toasted, not rancid | 6 | Slightly more crumbly. | Fairly bland but with slightly parched cereal taste. | 6 |
| D-1 Peanut | 0 | Light brown | Peanut - good | 8 | Quite hard, but biteable. | Somewhat flat mild peanut. | 7 |
| | 100 | Slightly browner | Same, but slightly stale not rancid | 6 | Slightly less hard, more crunch. | Stale, slightly rancid. | 5 |
| D-2 Coconut | 0 | White | Coconut - good | 8 | Definitely hard-probably too hard to bite. | Coconut, sweet-good. | 8 |

TABLE XXIII (Concluded)

| Sample | Storage Temp. (°F) | Color | Odor | Rating[a] | Bite | Flavor | Rating |
|---|---|---|---|---|---|---|---|
| D-2 Coconut (Concluded) | 100 | Slightly orange, yellow-white | Coconut, very slightly stale | 7 | Slightly more brittle, cracks more easily. | Some off-flavor, slightly stale | 6 |

a/ Nine point hedonic scale.

TABLE XXIV

EFFECT OF THREE MONTHS' STORAGE AT 100°F ON THE PHYSICAL PROPERTIES OF PROTOTYPE BLOCKS

| Formula | Moisture (%) | Breaking Strength (lb.) | 10-ft. Drop Loss (Room temp.) (%) | % Deformation in 24 hr. Under 5 psi Pressure at 100°F: Vertical Shrinkage (%) | Lateral Expansion (%) |
|---|---|---|---|---|---|
| B-1 Bacon | | | | | |
| Fresh[a] | 14.1 | 21.3 | - | 6 | 0 |
| Stored | -[b] | 22.1 | 1.8 | 0 | 0 |
| B-2 Chicken | | | | | |
| Fresh | 5.3 | 30 | 0.9 | 0 | 0 |
| Stored | - | 30[c] | 8.5 | 5 | 0 |
| B-3 Beef | | | | | |
| Fresh | 4.3 | 30 | 0.4 | 0 | 0 |
| Stored | - | 22.6 | 0.3 | 0 | 0 |
| C-3 Soy Cracker | | | | | |
| Fresh | 5.5 | 30 | 0.4 | 3 | 1 |
| Stored | - | 30 | 0.1 | 6 | 0 |
| D-1 Peanut | | | | | |
| Fresh | 12.4 | 30 | 0.5 | 6 | 0 |
| Stored | - | 30 | 0 | 0 | 0 |
| D-2 Coconut | | | | | |
| Fresh | 11.0 | 18 | 1 | 28 | 5 |
| Stored | - | 30 | 4.3 | 5 | 0 |

a/ The values were obtained on a separate series of blocks, prepared before the storage test.

b/ Moisture was not run on the stored blocks. Since they were stored in sealed jars, it can be assumed that the moisture loss was negligible.

c/ The figure "30" represents a breaking strength of 30 lb. or more.

TABLE XXV

PHYSICAL TEST RESULTS ON SIX PROTOTYPE BLOCK FORMULAS SHIPPED TO THE SPONSOR

| Formula | B-1 Bacon | B-2 Chicken | B-3 Beef | C-3 Soy-Cracker | D-1 Peanut | D-2 Coconut |
|---|---|---|---|---|---|---|
| Breaking strength, lb. | 12.5 | 30[a] | 30 | 29.6 | 30 | 30 |
| 10-ft. drop loss, % | 4.9 | 1.5 | 0.3 | 16.0 | 1.3 | 3.0 |
| Shear strength, lb. | 9.3 | 33.6 | 27.4 | 14.6 | 32.9 | 35.0 |
| Impact resistance range, lb. | 1-2 | 4-5 | 20-22 | 1-2 | 5-6 | 2-3 |

a/ The figure "30" indicates a breaking strength of 30 lb. or higher.

TABLE XXVI

EFFECT OF FINAL MOISTURE CONTENT ON THE DEFORMATION OF FORMULA BLOCKS MADE WITH 10% INSTANT STARCH BINDER

| Basic Moisture Content of Blocks (%) | Temperature (°F) | % Deformation in 24 hr. under 5 psi Pressure: Vertical Shrinkage (%) | Lateral Expansion (%) |
|---|---|---|---|
| 18 | 75 | 4 | 1 |
| | 100 | 4 | 3 |
| 23 | 40 | 2 | 0 |
| | 75 | 9 | 2 |
| | 100 | 23 | 8 |
| 26 | 40 | 3 | 1 |
| | 75 | 15 | 4 |
| | 100 | 29 | 18 |

TABLE XXVII

COMPARATIVE SHEAR VALUES OBTAINED ON FOOD BLOCKS OF VARIOUS DEGREES OF RESISTANCE TO BITE

| Food Block | Resistance to Biting Off and Chewing | Shear Strength Values (lb.): How Obtained | Shear Strength Values (lb.): Individual Values | Shear Strength Values (lb.): Avg. |
|---|---|---|---|---|
| Small basic formula block, made with milk-dusted bacon. Dense. | Soft and rubbery, very easy to chew | On individual blocks | 5.9<br>7.6<br>8.4 | 7.3 |
| Small basic formula block, milk-dusted bacon. Loosely compacted. | Very soft | On individual blocks | 2.5<br>4.0<br>3.4 | 3.3 |
| Small basic formula block. Milk-dusted bacon. Medium - dense. | Fairly soft | On individual blocks | 6.3<br>2.8<br>5.9 | 5.0 |
| Small block made from crackers. | Fairly brittle, but easily chewed | On individual blocks | 19.5<br>14.0<br>19.5 | 17.6 |
| Small peanut-rice block, formula D-1. | Too hard to bite | On individual blocks | 35.8<br>36.2 | 36.0 |
| Small defatted peanut-milk block, formula D-3. | Old sample, very hard | On individual blocks | 38.2<br>32.4 | 35.3 |

TABLE XXVII (Continued)

| Food Block | Resistance to Biting Off and Chewing | Shear Strength Values (lb.): How Obtained | Individual Values | Avg. |
|---|---|---|---|---|
| Dog biscuits - "milk bone" for medium dogs. National Biscuit Co. Approx. 1/2" x 3/4" cross section at center. | Very hard. Can be bitten off and chewed only with great difficulty. These are about as hard a block as teeth can handle. | Individual biscuits, sheared in middle. | 28.0<br>28.5<br>28.9<br>27.6<br>23.8<br>22.5<br>32.6<br>19.4<br>20.3 | 25.7 |
| Raw turnip, sliced lengthwise into 1/2" x 1-1/4" sections. | Slightly harder than an uncooked apple. | Through single section, first turnip | 9.0<br>19.6<br>13.2 | 13.9 |
| | | Through single section, first turnip | 12.9<br>12.4 | 12.7 |
| | | Through single section, second turnip | 13.1<br>11.3<br>12.2<br>11.2 | 12.0 |
| | | Through single section, second turnip | 15.7<br>13.8<br>13.6 | 14.4 |

TABLE XXVII (Concluded)

| Food Block | Resistance to Biting Off and Chewing | Shear Strength Values (lb.) | | |
|---|---|---|---|---|
| | | How Obtained | Individual Values | Avg. |
| Raw potato (Kaw Valley Cobbler), sliced lengthwise into 1/2" x 1-1/4" sections. | A little harder than turnip | Series of sections from a single potato | 17.3<br>14.9<br>15.8 | 16.0 |
| | | | 18.1<br>14.9 | 16.5 |
| | | | 14.6<br>14.6 | 14.6 |
| | | | 15.2<br>15.2 | 15.2 |

TABLE XXVIII

IMPACT BREAKING RANGES OBTAINED ON FOOD BLOCKS OF VARIOUS DEGREES OF SOLIDITY

All Values are in Inch-Pounds

| Food Block | Values | Range |
|---|---|---|
| Soft, crumbly small basic formula blocks made with milk-dusted bacon. | < 4, < 6, < 3, < 3 | 2-3 |
| Dog biscuits - "milk bone" for medium dogs. Impact at approx. 1/2 x 3/4 in. center section. | < 10, < 6, < 4, < 2, > 1, < 1, < 1, < 1, < 1, > 1, > 1, < 1 | 0-2 |
| Turnip, 1-1/4 x 1-1/4 x 1/2 in. section. | Firm piece<br>> 6, > 8 | > 8 |
| | Soft piece<br>> 4, < 6, < 8 | 4-6 |
| | Firm piece<br>> 8, > 10, > 10, < 12, > 12, < 12, > 12 | 10 - > 12 |
| | Very soft piece<br>> 4, > 6, > 8, < 10, < 10 | 8-10 |
| Potato, 1-1/4 x 1-1/4 x 1/2 in. sections. | < 10, < 6, < 4, > 3, < 4, > 3 | 3-4 |
| | < 6, > 4, < 5 | 4-5 |

Unclassified

Security Classification

## DOCUMENT CONTROL DATA - R&D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>Midwest Research Institute, Kansas City, Missouri | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified<br>2b. GROUP |

3. REPORT TITLE

DEVELOPMENT OF FOOD BARS EMPLOYING EDIBLE STRUCTURAL AGENTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report 10 April 1962 - 10 April 1963

5. AUTHOR(S) (Last name, first name, initial)

Newlin, H. E. and Morris, E. R.

| | | |
|---|---|---|
| 6. REPORT DATE<br>August 1965 | 7a. TOTAL NO. OF PAGES<br>82 | 7b. NO. OF REFS<br>0 |
| 8a. CONTRACT OR GRANT NO.<br>DA19-129-QM-1984 (OI 6071)<br>b. PROJECT NO.<br>7X84-06-031<br>c.<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>2591-C<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>FD-20 | |

10. AVAILABILITY/LIMITATION NOTICES

Available at DDC and CFSTI

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY<br>Animal Products Branch, Food Division,<br>U. S. Army Natick Laboratories,<br>Natick, Mass. 01762 |

13. ABSTRACT

Several pastes and a hot melt prepared from edible components were found effective binders for preparation of bars from any combination of dry foods. Effectiveness of these edible binders was demonstrated on bars prepared from different types and compositions of foods. Bars remained acceptable after storage for three months at $100^{o}F$. and retained adequate resistance to impact and shear.

| KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Adhesiveness | | | | | 1 | |
| Brittleness | | | | | 1 | |
| Chewiness | | | | | 1 | |
| Gumminess | | | | | 1 | |

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

DISTRIBUTION

Copies

1 - Commanding General
U.S.Army Weapons Command
Attn: AMSWE-RDR
Rock Island, Illinois

1 - Commanding General
USA Test & Evaluation Command
Attn: AMSTE-TAA
Aberdeen Proving Ground, Maryland

1 - Commanding General
U.S.Army Nuclear Defense Laboratory
Army Chemical Center
Maryland

1 - Commanding General
United States Continental Army Command
Attn: DCSLOG, Maintenance Division
Fort Monroe, Virginia

1 - Commanding General
USA Combat Developments Command
Attn: CDCMR-O
Fort Belvoir, Virginia

1 - Commanding General
U.S.Army Mobility Command
Attn: AMSMO-RR
Warren, Michigan

1 - Commanding Officer
U.S.Army Polar Research & Dev Ctr
Fort Belvoir, Virginia

1 - Commanding General
U.S.Army Edgewood Arsenal
Attn: Directorate of Commodity Mgmt
Edgewood Arsenal, Maryland

1 - Commanding General
U.S.Army Electronics Research and Development Laboratories
Attn: Tech Info Div
Fort Monmouth, N.J.

1 - Commanding Officer
U.S.Army Materials Research Agency
Attn: Technical Library
Watertown, Mass. 02172

1 - Commanding Officer
USACDC Nuclear Group
Fort Bliss, Texas 79916

1 - Commanding Officer
US Army Combat Developments Command
Combat Service Support Group
Fort Lee, Virginia 23801

1 - Commanding Officer
US Army Combat Developments Command
Quartermaster Agency CDCQMA-F
Fort Lee, Virginia

2 - Commanding Officer
Cold Weather & Mountain Indoctrination School
Fort Greely, Alaska

1 - Commanding Officer
U.S.Army Research Office-Durham
Attn: CRD-AA-IP
Box CM, Duke Station
Durham, North Carolina

Copies

1 - Commanding Officer
U.S.Army Cold Regions Research & Engineering Laboratories
Hanover, New Hampshire

1 - Commanding Officer
U.S.Army Human Engineering Labs
Aberdeen Proving Ground
Maryland

1 - Commanding Officer
US Army Coating & Chemical Labs
Aberdeen Proving Ground, Maryland

1 - Directorate of Training Literature
U.S.Army Transportation School
Fort Eustis, Virginia 23604

1 - Directorate of Science & Technology
DCS/Research & Development
Hq., U.S.Air Force
Washington 25, D.C.

1 - Directorate of Science & Technology
AFRSTD
DCS/R&D
Hq., United States Air Force
Washington, D.C. 20330

1 - Defense Director, Technical Info
Office of Director of Defense Research & Engineering
Room 3D1040 Pentagon
Washington 25, D.C.

1 - Director
U.S.Army Engineer Research and Development Laboratories
Attn: Technical Document Center
Fort Belvoir, Virginia

1 - Director
Air University Library
Attn: AUL3T-7575
Maxwell AFB, Alabama 36112

1 - Director
Biological Sciences Div
Office of Naval Research
Department of the Navy
Washington, D.C. 20360

1 - Director, Library
US Army War College
Carlisle Barracks,Pa.17013

2 - Director
Aerospace Crew Equip Lab
Naval Air Engr Center
Philadelphia, Pa. 19112

1 - Director
Marine Corps Landing Force Development Center
Marine Corps Schools
Attn: Ground Combat Divn
Quantico, Virginia 22134

1 - Director
Engineering & Ind Svcs
Attn: Directorate of Chemical Engineer
Edgewood Arsenal, Maryland

1 - Director,
Army Technical Information
U.S.Army Research Office
OCRD, Room 209A
Arlington 4, Virginia

4 - Commandant
U.S.Army Quartermaster School
Attn: Quartermaster Library
Fort Lee, Virginia, 23801

1 - Commandant
USA Armor School
Attn Ch, Pol & Tng Lit Div
Fort Knox, Ky.

Copies

2 - Commandant
United States Army Infantry School
Attn: AJIIS-A
Fort Benning, Georgia

1 - Commandant of the Marine Corps
Code AO4D
Washington 25, D.C.

1 - Commander
U.S.Naval Ordnance Test Station
Attn: Code 12
China Lake, Calif. 93557

1 - Commander
U.S.Army Chemical Research & Devel. Lab
Attn: Tech Library
Edgewood Arsenal, Maryland

1 - Commander
U.S.Army Biological Labs
Attn: Tech Library
Fort Detrick
Frederick, Maryland

1 - President
Hq., US Army Artillery Board
Fort Sill, Oklahoma 73504

1 - President
U.S.Army Arctic Test Board
APO 733 Seattle, Washington

1 - President
U.S.Army Aviation Test Board
Fort Rucker, Alabama 36362

1 - President
U.S.Army Infantry Board
Ft. Benning, Georgia 31905

1 - President
U.S.Army Armor Board
Fort Knox, Kentucky 40121

1 - The Army Library
Attn: Procurement Section
Room 1A522, The Pentagon
Washington, D.C. 20310

1 - Library
U.S.Weather Bureau
Washington, D.C. 20235

1 - Air Force Cambridge Research Labs
Laurence G. Hanscom Field
Attn: CRMXLR, Res Library, Stop 29
Bedford, Massachusetts 01731

1 - U.S.Army Aviation School Library
Bldg. 5313
Fort Rucker, Alabama

2 - Chief, Status and Support Branch
Maintenance Readiness Division
U.S.Army Supply & Maint. Command
Washington, D.C. 20315

2 - USA NLABS Ln Office
ASDL-8
Wright-Patterson AFB, Ohio

1 - US Army Ballistic Research Lab
Attn AMXBR-TC, Mr.B.F.Armendt
Aberdeen Proving Ground,Md. 21005

1 - United States Dept of Agriculture
Division of Acquisitions
National Agricultural Library
Washington, D.C. 20250

1 - Library
US Army Airborne, Electronics & Special Warfare Board
Fort Bragg, North Carolina

1 - U.S. Atomic Energy Commission
Reports Section, Hdqrs Library
Mail Station G-017
Division of Technical Information
Washington, D.C. 20545

Copies

1 - ACOFS, G3
Hq, U.S. Army Combat
Developments Com
Experimentation Center
Fort Ord, California 93941

2 - Redstone Scientific Information
Center
U.S. Army Missile Command
Attn: Chief, Documents Section
Redstone Arsenal, Alabama

6 - U.S. Army Special Warfare School
Attn: Assistant Secretary
Director of Instruction
Fort Bragg, NorthCarolina 28307

3 - U.S. Atomic Energy Commission
Division of Technical Information
Extension
P.O. Box 62
Oak Ridge, Tennessee 37831

1 - U.S. Naval Research Laboratory
Code 6140
Washington, D.C. 20390

1 - Chief, Bureau of Ships
Room 2510, Main Navy
Code 364A4
18th & Constitution Ave., N.W.
Washington, D.C.

1 - Chief, Programs & Policy Office
Directorate of Tech Operations
DCTSC
2800 South 20th Street
Philadelphia, Pa. 19101

1 - U.S. Naval Applied Science Lab
Technical Library
Building 291, Code 9832
Naval Base
Brooklyn, New York 11251

1 - U.S. Army Command & Gen Staff
College
Library Division
Fort Leavenworth, Kansas 66027

2 - Exchange and Gift Division
Library of Congress
Washington, D.C. 20540

2 - Chief, Supply Division
Logistics Services
Hq, Fort Monmouth
Vail Hall, Bldg. 1150
Fort Monmouth, New Jersey 07703

1 - Department of the Navy
Special Projects Office
Washington, D.C. 20360

1 - Officer in Charge
NAVSUPRANDFAC
Bldg 82, Naval Supply Center
Attn: Library
Bayonne, New Jersey

1 - Arctic AEROMED Laboratory
Attn: Librarian
APO 731, Seattle, Washington

1 - U.S. Army Materiel Command
Research Division AMCRD-RL
R&D Directorate
Bldg. T-7
Washington, D.C. 20315

1 - U.S. Army Engineering Research
Development Laboratories
Attn: STINFO Branch
Fort Belvoir, Virginia

1 - Library
U.S. Naval Supply Research and
Development Facility
Naval Supply Center
Bayonne, New Jersey 07002

Copies

1 - Reference Center Library
The Institute for Cooperative
Research
Eglin Facility
P.O. Box 1867
Eglin Air Force Base, Florida

1 - Mr. Gerald Chaikin
U.S. Army Missile Command
Attn: AMSMI-PC
Redstone Arsenal, Alabama

1 - National Research Council
University of Rhode Island
Kingston, Rhode Island

DATE PRINTED: 1 June 1965
(Revised)